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NATIONAL DAM SAFETY PROGRAM, NEW VIBURNUM TAILINGS DAM (MO 3123--ETC(U)

APR 81 J PEREZ, R G BERGGREEN

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# MISSISSIPPI-KASKASKIA-ST. LOUIS BASIN

NEW VIBURNUM TAILINGS DAM  
IRON COUNTY, MISSOURI  
MO 31231

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## PHASE 1 INSPECTION REPORT NATIONAL DAM SAFETY INSPECTION



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20. ABSTRACT (Continue on reverse side if necessary and identify by block number) <b>This report was prepared under the National Program of Inspection of Non-Federal Dams. This report assesses the general condition of the dam with respect to safety, based on available data and on visual inspection, to determine if the dam poses hazards to human life or property.</b>		

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**NEW VIBURNUM TAILINGS DAM**

Iron County, Missouri

Missouri Inventory Number 31231

**Phase I Inspection Report  
National Dam Safety Program**

Prepared by

**Woodward-Clyde Consultants**

Chicago, Illinois

Under Direction of  
St Louis District, Corps of Engineers

for  
Governor of Missouri  
April 1981

## PREFACE

*This report is prepared under guidance contained in the Recommended Guidelines for Safety Inspection of Dams for Phase I Investigations. Copies of these guidelines may be obtained from the Office of the Chief of Engineers, Washington, D. C., 20314. The purpose of a Phase I investigation is not to provide a complete evaluation of the safety of the structure nor to provide a guarantee on its future integrity. Rather the purpose of the program is to identify potentially hazardous conditions to the extent they can be identified by a visual examination. The assessment of the general condition of the dam is based upon available data (if any) and visual inspections. Detailed investigations, testing, and detailed computational evaluations are beyond the scope of a Phase I investigation; however, the investigation is intended to identify the need for more detailed studies. In view of the limited nature of the Phase I studies no assurance can be given that all deficiencies have been identified.*

*In reviewing this report, it should be realized that the reported condition of the dam is based on observations of field conditions at the time of inspection along with any data which may be available to the inspection team. In cases where the reservoir was lowered or drained prior to inspection, such action removes the normal load on the structure, as well as the reservoir head along with seepage pressures, and may obscure certain conditions which might otherwise be detectable if inspected under the normal operating environment of the structure.*

*It is important to note that the condition of a dam depends on numerous and constantly changing internal and external conditions, and is evolutionary in nature. It would be incorrect to assume that the present condition of the dam will continue to represent the condition of the dam at some point in the future. Only through frequent inspections can unsafe conditions be detected, so that corrective action can be taken. Likewise continued care and maintenance are necessary to minimize the possibility of development of unsafe conditions.*



PHASE I REPORT  
NATIONAL DAM SAFETY PROGRAM

Name of Dam	New Viburnum Tailings Dam
State Located	Missouri
County Located	Iron
Stream	Unnamed Tributary of Indian Creek
Date of Inspection	24 February 1981

New Viburnum Tailings Dam, Missouri Inventory Number 31231, was inspected by Richard Berggreen (engineering geologist), Pierre Mallard (geotechnical engineer), Jean-Yves Perez (geotechnical engineer), and Sean Tseng (hydrologist). The dam is being constructed of lead tailings on top of an earth starter dam. It impounds lead tailings.

The dam inspection was made following the guidelines presented in the "Recommended Guidelines for Safety Inspection of Dams." These guidelines were developed by the Chief of Engineers, U.S. Army, Washington, D.C., with the help of federal and state agencies, professional engineering organizations, and private engineers. The resulting guidelines represent a consensus of the engineering profession. These guidelines are intended to provide for an expeditious identification of those dams which may pose hazards to human life and property, based on available data and visual inspection of the dam. In view of the limited nature of the study, no assurance can be given that all deficiencies have been identified.

The St Louis District (SLD), Corps of Engineers, has classified this dam as having a high hazard potential. The SLD estimated damage zone length extends approximately 15 miles downstream of the dam. Within five miles downstream are several dwellings, a church, a quarry and the town of Courtois. The contents of a portion of the damage zone were verified by aerial reconnaissance.

New Viburnum Tailings Dam is classified large size based on its present height of approximately 110 ft. The present storage capacity to the spillway crest is approximately 4750 ac-ft, of which approximately 4000 ac-ft is tailings. The large size dam classification includes dams higher than 100 ft, or having storage capacity greater than 50,000 ac-ft, whichever gives the larger classification.

On the basis of the visual inspection, review of available data, and inspection of aerial photos, the dam is judged to be in poor condition. This judgement is based on observation of uncontrolled seepage and associated slumping at the downstream toe of the dam, the

presence of a large, 20 to 30 ft diameter sinkhole on aerial photos of the dam taken in November 1980, and lack of knowledge on the remedial measures taken to repair the sinkhole. No evidence was noted of cracking, extensive erosion, deep seated slope instability, or settlement of the crest. During the field inspection in February 1981, we did not detect the presence of the sinkhole, but did observe a drain pipe flowing at the rate of about 125 gal/min, a zone of wet tailings, and uncontrolled seepage and slumping, in the area where the sinkhole existed in November 1980. A brief reconnaissance of the dam in April 1981 noted a crater-like depression in the vicinity of the past sinkhole, suggesting the sinkhole repairs were not successful on a permanent basis. A thorough investigation of the piping phenomenon is required to better assess the present condition and the probable future safety of this dam. This investigation is beyond the scope of this Phase I inspection.

The embankment material is judged highly susceptible to erosion by flowing water. Seepage and stability analyses comparable to the guidelines are not on record, which is considered a deficiency. Hydraulic and hydrologic analyses indicate that the reservoir and the present spillway are capable of handling the Probable Maximum Flood (PMF) without overtopping the dam. The guidelines require large dams in the high hazard classification to pass 100 percent of the PMF as the spillway design flood. The PMF is defined as the flood event that may be expected to occur from the most severe combination of critical meteorologic and hydrologic conditions that are reasonably possible in the region.

It is recommended the following measures and studies be implemented under the guidance of an engineer experienced in the design, construction, and maintenance of tailings dams.

- a. A thorough investigation of the conditions associated with the past sinkhole should be undertaken immediately, including a review of the history of the sinkhole development and remedial measures taken. This investigation should address the causes of the sinkhole, the potential for future sinkhole activity on this dam, and the affect of such features on the dam stability. Particular attention should be directed to the position of the phreatic surface within the dam under present conditions and when the reservoir level is 20 ft higher after the embankment is completed.
- b. During and after the construction of the dam, periodic inspection of the embankment should be made to detect erosion due to runoff, spring flow, and seeping water. Records of these inspections should be kept.

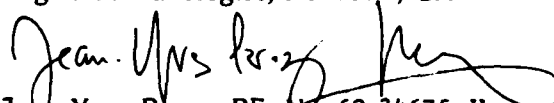
- c. A program for erosion protection of the surface of the embankment should be prepared.
- d. Seepage and stability analyses comparable to the requirements of the "Recommended Guidelines for Safety Inspection of Dams" should be made for appropriate loading conditions, including earthquake loads, and made a matter of record. These analyses should take into account the effects of changes in the phreatic surface, especially for full reservoir level.
- e. The feasibility of a practical and reliable warning system should be evaluated to alert downstream residents and traffic in the event hazardous conditions develop at this dam during periods of flooding.

Measures concerning periodic inspections and evaluation of potential piping at the toe of the dam should be performed immediately. Other studies should be done as soon as practical.

WOODWARD-CLYDE CONSULTANTS



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Jean-Yves Perez, PE, No. 62-34675, IL  
Vice-President



OVERVIEW  
NEW VIBURNUM TAILINGS DAM

MISSOURI INVENTORY NUMBER MO 31231

PHASE I INSPECTION REPORT  
NATIONAL DAM SAFETY PROGRAM  
NEW VIBURNUM TAILINGS DAM, MISSOURI INVENTORY NO. 31231  
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- 3-B. Dam and Spillway Cross Sections
4. Regional Geologic Map

## APPENDICES

### A Figure A-1: Photo Location Sketch

#### Photographs

1. View of the downstream face of New Viburnum Tailings Dam near the right abutment. Note the present spillway on the left of the photograph and the former spillway under the low elevation tailings embankment.
2. Close-up photograph of tailings used for the construction of the dam embankment.
3. Cyclone installed on the crest of the embankment spreading slurries of the coarse-grained fraction used for the construction of the embankment.
4. Discharge pipe from the cyclone along the upstream face of the embankment.
5. Erosion of the upstream face of the embankment from previous discharge of fine tailings slurries into the reservoir. Looking northwest.
6. Erosion in the form of gullies at the top of the downstream face of the embankment near the left abutment. Note the pipe running along the crest and carrying tailings slurries to the cyclone.
7. Downstream toe of the embankment. Looking northeast. Note the tailings up to the settling pond in the background and the buried trees. Also note seepage erosion area at the immediate toe of the dam.
8. Aeolian dune face along downstream face of the right end of the embankment. Looking southeast.
9. Drain pipe at the toe of the dam near the right abutment.
10. Seepage at the toe of the downstream face of the embankment near the left abutment.
11. Seepage erosion at downstream toe of the embankment.
12. Present spillway. Looking west. Dam is out of picture to the right.
13. Aerial view of dam and reservoir. Looking northwest. Note the final spillway at the bottom left of the photo.

## APPENDICES

## Photographs (continued)

14. Earth berm along the ridge top on the right abutment of the dam. Looking north.
15. Aerial view of New Viburnum Tailings Dam in November 1980. Note sinkhole at toe of dam. Also note grayish tailings downstream of sinkhole that could be the result of recent internal erosion associated with the sinkhole.

- B Hydraulic/Hydrologic Data and Analyses
- C Design Drawings by St Joe Lead Co
- D Corps of Engineers Notification of Sinkholes

**PHASE I INSPECTION REPORT**  
**NATIONAL DAM SAFETY PROGRAM**  
**NEW VIBURNUM TAILINGS DAM, MISSOURI INVENTORY NO. 31231**

**SECTION 1**  
**PROJECT INFORMATION**

**1.1 General**

- a. **Authority.** The National Dam Inspection Act, Public Law 92-367, provides for a national inventory and inspection of dams throughout the United States. Pursuant to the above, an inspection was conducted of New Viburnum Tailings Dam, Missouri Inventory Number 31231.
- b. **Purpose of inspection.** "The primary purpose of the Phase I investigation program is to identify expeditiously those dams which may pose hazards to human life or property... The Phase I investigation will develop an assessment of the general condition with respect to safety of the project based upon available data and a visual inspection, determine any need for emergency measures, and conclude if additional studies, investigations, and analyses are necessary and warranted" (Chapter 3, "Recommended Guideline for Safety Inspection of Dams").
- c. **Evaluation criteria.** The criteria used to evaluate the dam were established in the "Recommended Guidelines for Safety Inspection of Dams," and Engineering Regulation No. 1110-2-106 and Engineering Circular No. 1110-2-188, "Engineering and Design National Program for Inspection of Non-Federal Dams" prepared by the Office of the Chief of Engineers, Department of the Army; and "Hydrologic/Hydraulic Standards, Phase I Safety Inspection of Non-Federal Dams," prepared by the St Louis District, Corps of Engineers. These guidelines were developed with the help of several federal and state agencies, professional engineering organizations, and private engineers.



## 1.2 Description of Project

- a. Description of dam and appurtenances. New Viburnum Tailings Dam is an active lead tailings dam. Although its construction and usage are typical of other lead tailings dams in the area, it is atypical of dams constructed for the impoundment of water. The unique nature of these lead tailings dams has a significant impact on their evaluation. A brief description of their construction and usage is necessary to distinguish the differences between these dams and conventional water-retaining dams.

The lead tailings dams in southeastern Missouri have been constructed over a long period of time and include dams ranging from very old abandoned dams constructed in the 1800's to new dams still under construction. Although the construction techniques have changed, these dams have many similarities.

At the beginning of a mining operation a starter dam is frequently constructed of waste rock and residual soil. This dam is used to impound surface runoff and mine water pumped from the underground workings. The water is used in the ore processing and the transport of tailings waste. The reservoir formed by the starter dam constitutes the initial tailings disposal area.

The tailings are the waste material produced by the beneficiation and processing of the lead ore to form a high-grade lead concentrate. The coarse tailings fraction (medium to fine sand) is used to construct the dam embankment; the fine fraction (very fine sand and silt) is deposited in the reservoir area. Separation of the coarse and fine fractions usually is done using a cyclone separator or a series of cyclones installed on the crest of the dam. The underflow or coarse fraction is deposited on the dam and the overflow or fine fraction is pumped into the reservoir to be deposited.

The dams are typically constructed using the downstream method. That is, as the tailings are added to the dam, they are deposited on the crest and downstream slope. As a result, the centerline of the dam crest migrates downstream, as the embankment is gradually raised.

Frequently, the dam has a drainage system built into the foundation to aid in lowering the phreatic surface (water table) within the embankment. Water enters the dam both at the crest from the cyclone-deposited tailings and at the upstream slope from the reservoir. The phreatic surface within the dam is relatively high near the operating cyclone. This is an important consideration when assessing the static and seismic stability of these sand embankments. A clay blanket is frequently constructed on the upstream face to reduce infiltration from the reservoir and to maintain a low phreatic surface within the dam.

A decant or water disposal system is typically constructed beneath the dam. This decant system consists of a vertical or sloping structure within the reservoir which decants or draws water from near the surface of the reservoir where the water contains the least sediment. This water is then carried beneath the dam through a large diameter pipe and exits below the toe of the dam. From there it may be recycled or released to the natural stream drainage. The intake level of the decant tower or structure is regulated as the tailings and reservoir level rises to maintain a balanced system of inflow and outflow. The decant system also serves as an outlet in the event of heavy precipitation, typically in addition to other spillway provisions.

Three characteristics are noteworthy regarding the silt and sand tailings used in the construction of these dams. First, the uniform grain size and lack of clay or other binder makes this material highly susceptible to erosion and/or piping. It is unlikely that dams built with this material could survive significant overtopping without failure. Second, the finely ground limestone and dolomite tailings are almost barren of nutrients necessary to support vegetation. It is frequently necessary to import topsoil or fertilizer in order to successfully vegetate the dam embankment. This difficulty in vegetating the surface of the dam contributes to the potential for erosion of the dam. Third, the cyclone-deposited tailings are not very dense. Coupled with the potential for a high phreatic surface during cycloning operations, these characteristics make the embankment susceptible to liquefaction in the event of significant seismic shocks.

The tailings impounded upstream of the dam consolidate fairly rapidly upon deposition, and once consolidated, will stand in near-vertical slopes of consider-

able height. These tailings are subject to erosion, but not flow. Based on inspection of a breached lead tailings dam, we believe a relatively small portion of the impounded tailings would be lost through a breach. It can be anticipated that failure of the dam would release the impounded water, but only a small portion of the tailings would be lost through a breach.

New Viburnum Tailings Dam is still under construction. Several of the typical lead tailings dams features described above do not apply to this dam. The coarse fraction of the tailings is deposited by cyclone on the centerline of the starter dam such that the centerline of the tailings embankment remains relatively constant and does not migrate downstream as the embankment is raised. The cross section of the dam is comparatively flat, with slopes on the order of 5(H) to 1(V) (Fig. 3A). There is no impervious blanket on the upstream face of the dam, no decant system and no extensive drainage system at the toe. A temporary spillway has been cut in the present right abutment of the dam. This spillway will be backfilled with clayey soil and the dam will extend over it when completed. At that time, overflow will pass through a permanent spillway already constructed at a higher elevation as a cut through natural ground about 1/4 mi south of the dam.

- b. **Location.** New Viburnum Tailings Dam is located on an unnamed tributary of Indian Creek, about 1 mi southeast of Viburnum, Iron County, Missouri (Fig. 1). The dam is in Section 36, T35N, R2W, on the USGS Viburnum East, Missouri 7.5-minute quadrangle map (1967).
- c. **Size classification.** The dam is classified as large, based on its present minimum height of approximately 110 ft. Final height will be approximately 130 ft. The present storage capacity to the temporary spillway elevation is 4750 ac-ft including both water and tailings. The majority of this, on the order of 4000 ac-ft, is occupied by tailings. Under the definitions in the "Recommended Guidelines for Safety Inspection of Dams," a large dam classification applies to dams over 100 ft in height, or having over 50,000 ac-ft of storage capacity, whichever gives the larger classification.

- d. **Hazard classification.** The St Louis District (SLD), Corps of Engineers, has classified this dam as having a high hazard potential; we concur with this classification. The SLD estimated damage zone length extends 15 mi downstream of the dam. Within 5 mi downstream are several dwellings, a church, a quarry and the town of Courtois. The contents of a portion of the estimated damage zone were verified by aerial reconnaissance. The potential for property damage and loss of life could be high in the event of dam failure.
- e. **Ownership.** We understand the dam is owned by St Joe Lead Co, PO Box 500, Viburnum, Missouri, 65566. Correspondence should be sent to the attention of Mr Jack Krokroskia.
- f. **Purpose of dam.** The dam impounds tailings produced in the milling and processing of lead ore mined in the vicinity. The dam is still under construction and is scheduled to be completed in fall 1981.
- g. **Design and construction history.** Information on the design and construction of New Viburnum Tailings Dam was obtained from interviews with Mr John Kennedy and Mr John Carter of St Joe Lead Co, and from maps and plans of the dam and reservoir supplied by St Joe Lead Co.

The dam was designed and is built by St Joe Lead Co. Construction of the dam began in 1971 and is expected to be completed during fall 1981. Tailings disposal in the reservoir is expected to continue until 1988.

According to the information obtained from St Joe Lead Co, a 30-ft high, rolled earth starter dam was first constructed across the valley. A cutoff trench, 5 ft deep, 30 ft wide was excavated into the "impervious" subgrade material along the starter dam alignment. A 24-in. diameter pipe was installed through the starter dam to evacuate runoff from upstream of the starter dam during its construction. A drawing showing design details of the starter dam is presented in Appendix C.

Prior to the construction of the tailings embankment over the starter dam, the 24-in. diameter pipe was plugged (probably by welding plates to it) and a crushed stone drainage blanket was installed at the downstream end of the pipe. At present, a 12-in. diameter pipe exits the toe of the dam near the right abutment. Clear water was flowing out of this pipe at the rate of approximately 125 gal/min at the time of the field inspection. According to St Joe Lead Co personnel, the 12-in. pipe and associated crushed stone drain were installed some time ago to drain a spring on the right abutment and also to drain water seeping through the dam. As discussed elsewhere in this report (Section 2.4.a), it was found out later that a sinkhole had developed near the pipe (as used in this report, the term "sinkhole" is intended to describe a cone-shaped topographic depression with steep slopes, resembling a crater).

The embankment is currently being constructed of coarse lead tailings (medium to fine sand) deposited by a cyclone separator located on the crest of the dam. The finer fraction of the tailings is discharged through a pipe to the upstream side of the embankment. The cyclone is moved from the left (northwest) abutment to the right (southeast) abutment, building successive 20-ft thick layers of embankment. At present, the cyclone is building the last such layer from about elevation 1160 ft to elevation 1180 ft. Approximately 1800 ft of the dam crest is currently at elevation 1180; approximately 1100 ft is at elevation 1160 (see Fig. 3-A and Overview Photograph). St Joe Lead Co. estimates that the entire dam crest will reach elevation 1180 by fall 1981.

Temporary spillways consisting of trapezoidal cuts through the right abutment ridge are provided for each successive increment of embankment level. As the dam is raised, the previous spillway cuts are backfilled and new spillway cuts are made higher on the abutment. At present, the lowest controlling temporary spillway cut has an invert elevation of 1145. This spillway will be backfilled soon as the dam crest is completed at elevation 1180. The permanent spillway is already constructed, about 1/4 mi south of the embankment. The permanent spillway has an invert elevation of 1165. It is important to note that this will raise the operating water level in the reservoir by at least 20 ft, as compared to the condition observed during our inspection.

According to St Joe Lead Co, following the completion of the dam which is scheduled for fall 1981, the downstream slope of the dam as well as the upstream slope above reservoir level will be vegetated to provide erosion protection.

- h. Normal operational procedures. There are no facilities requiring operations at this dam.

### 1.3 Pertinent Data

- a. Drainage area. 1.19 mi<sup>2</sup>

- b. Discharge at dam site.

Maximum known flood at damsite	Unknown
Warm water outlet at pool elevation	N/A (not applicable)
Diversion tunnel low pool outlet at pool elevation	N/A
Diversion tunnel outlet at pool elevation	N/A
Gated spillway capacity at pool elevation	N/A
Gated spillway capacity at maximum pool elevation	N/A
Ungated spillway capacity at maximum pool elevation	8140 ft <sup>3</sup> /sec
Total spillway capacity at maximum pool elevation	8140 ft <sup>3</sup> /sec

- c. Elevations (ft above MSL).

Top of dam	1160; will be entirely at 1180 by fall 1981
Maximum pool-design surcharge	N/A
Full flood control pool	N/A
Recreation pool	N/A
Spillway crest (gated)	N/A
Upstream portal invert diversion tunnel	N/A
Downstream portal invert diversion tunnel	N/A
Streambed at centerline of dam	1050
Maximum tailwater	Unknown
Toe of dam at maximum section	1050 (surveyed by St Joe Lead Co.)

d. Reservoir.

Length of maximum pool	4500 ft
Length of recreation pool	N/A
Length of flood control pool	N/A

e. Storage (acre-feet).

Recreation pool	N/A
Flood control pool	N/A
Design surcharge	N/A
Top of dam	7460
Spillway crest	4750 (approx 4000 occupied by tailings.)

f. Reservoir surface (acres).

Top of dam	207
Maximum pool	207
Flood control pool	N/A
Recreation pool	N/A
Spillway crest	154

g. Dam.

Type	Cyclone deposited lead tailings
Length	3000 ft
Height	110 ft (Feb 1981), will reach 130 ft by fall 1981.
Top width	18 ft (minimum)
Side slopes	Upstream field measured at 5.7(H) to 1(V) Downstream surveyed at 5(H) to 1(V)
Zoning	Reported to have earth fill starter dam covered with tailings.
Impervious core	None reported

Cutoff	Keyed into "impervious" subgrade material; trench reported to be 5 ft deep and 30 ft wide.
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Grout curtain	None
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h. Diversion and regulating tunnel.

Type	None
Length	N/A
Closure	N/A
Access	N/A
Regulating facilities	N/A

i. Spillway.

(1) Conditions at time of inspection:

Type	Trapezoidal cut in clayey residual soil through right abutment ridge. Side slopes 1.5-2.0(H) to 1(V).
Length of weir	No weir. The spillway is 40 ft wide at bottom.
Crest elevation	1145 ft
Gates	None
Downstream channel	Steep slope (4 (H) to 1(V)), unlined.

(2) Design conditions for end of dam construction:

Type	Trapezoidal cut in residual soil and weathered rock through ridge about 1200 ft south of dam
Length of weir	No weir. The spillway is 40 ft wide at bottom. Side slopes are 2(H) to 1(V).
Crest elevation	1165 ft
Gates	None
Downstream channel	Steep hill, unlined, vegetated with trees.

j. Regulating outlets. None



## SECTION 2 ENGINEERING DATA

### 2.1 Design

The dam was designed by St Joe Lead Co, Bonne Terre, Missouri, Engineering Department. A plan of the dam as well as a topography map of the valley were made available (Appendix C). Mr John Kennedy and Mr John Carter of St Joe Lead Co. supplied additional information through interviews with the inspection team.

### 2.2 Construction

The dam is being constructed by St Joe Lead Co. Construction of the dam started in 1971; the dam embankment is expected to be completed in fall 1981. Tailings disposal upstream of the dam is expected to continue until 1988.

An earth starter dam, about 900 ft long, was constructed across the valley at a crest elevation of 1080, according to the design plan. It was keyed into "impervious" subgrade material, the cutoff trench being 5 ft deep and 30 ft wide. No data was obtained concerning the exact nature of the material used for the starter dam. It is likely that it was constructed of residual clayey soil in the area. A 24-in. diameter, 160-ft long pipe, was installed across the starter dam, 400 ft from the left abutment of the dam to evacuate runoff water from upstream during the construction of the starter dam.

Prior to the construction of the tailings embankment over the starter dam, the 24-in. pipe was plugged and a crushed stone drain was installed at the downstream toe of the starter drain. A spring was reported to be present in the right abutment of the dam. A 12-in. diameter pipe currently exits at the toe of the dam near the right abutment. This pipe is reportedly connected to a crushed stone drain built to collect the spring water. No information concerning either the exact location or the extent of the crushed stone drain and the 12-in. pipe was made available to the inspection team.

The tailings embankment is constructed of medium- to fine-grained sand tailings deposited from a cyclone separator located at the crest of the dam. The dam crest is raised maintaining approximately constant centerline over the starter dam. The crest of the dam is raised in successive 20-ft thick layers by periodically moving the cyclone along the centerline of the dam. The minimum crest width is presently 18 ft. The minimum elevation of the embankment is 1160; the left portion of the dam is at the final elevation of about 1180 over a length of 1800 ft from the left abutment. The upstream and downstream slopes of the tailings embankment were designed at 3(H) to 1(V) but the actual slopes are approximately 5(H) to 1(V).

During the various stages of construction, trapezoidal trenches were cut in the right abutment ridge to act as temporary spillways. The width of these trenches was about 40 ft at the base. As the crest of the dam was raised, the superceded spillways were backfilled with natural clayey soil and covered by the tailings embankment. A former spillway partially covered by the tailings embankment can still be recognized on the right abutment of the dam about 50 ft below the present spillway (Photo 1). The final spillway has already been constructed about 1/4 mi south of the dam. It consists of a trapezoidal cut through residual soil and weathered rock, approximately 40 ft wide at its base.

Following the completion of the dam, which is expected in fall 1981, the downstream slope of the dam as well as the upstream slope above the reservoir level will reportedly be vegetated to provide erosion protection.

### 2.3 Operation

Water level in the reservoir is currently controlled by the ungated spillway at elevation 1145 on the right abutment of the dam. When the dam is at its final elevation of 1180, the final spillway, located 1/4 mile south of the dam and already constructed at elevation 1165, will control the operating water level in the reservoir.

No formal records are available on the history of flow through the spillways or reservoir levels. No evidence or record of overtopping of the dam or flow through the present spillway was noted during the visual inspection.

## 2.4 Evaluation

- a. **Availability.** The available information on engineering and construction is limited to the drawings presented in Appendix C and interviews with St Joe Lead Co. personnel. In addition, aerial photographs taken by us in November 1980 while inspecting other dams in the vicinity of Viburnum were examined. The photographs of the downstream face of the New Viburnum Tailings Dam show a sinkhole estimated to be 20 to 30 ft in diameter. This sinkhole appears to have been located in the vicinity of the 12-in. diameter drain pipe. This sinkhole appears to be the result of piping of tailings from the vicinity of the toe drain. From the information available to us it would appear that such piping may have been caused by: (1) excessive internal drainage velocities of seepage through the embankment, (2) a break in the 12-in. drain pipe, (3) the activity of the reported spring, or (4) some other causes. The occurrence of this piping and the resulting sinkhole is deemed to be of significant importance in the evaluation and assessment of the probable future stability and safety of this dam.
- b. **Adequacy.** The available information is insufficient to evaluate the design of New Viburnum Tailings Dam. The available information is also insufficient to evaluate the repairs made to the sinkhole which developed at the toe of the dam.

Seepage and stability analyses comparable to the requirements of the guidelines are not on record. This is a deficiency that should be rectified. These seepage and stability analyses should be performed for appropriate loading conditions (including earthquake loads) and made a matter of record. These analyses should be performed by a professional engineer experienced in the design and construction of tailings dams.

- c. **Validity.** Features of the design such as the configuration of the starter dam, cutoff trench and construction drainage pipe, as well as other features such as the nature and extent of the drainage system downstream of the starter dam, could not be verified. The slopes of the dam were substantially flatter than intended by the designer.

## 2.5 Project Geology

In the area of the dam location, bedrock is mapped on the Geologic Map of Missouri (1979) as the Potosi and Eminence Dolomite. The Potosi Dolomite, a light gray fine- to very fine-grained, silicious dolomite, typically contains an abundance of quartz druse associated with chert deposits within the formation. The Eminence Dolomite, which conformably overlies the Potosi Dolomite, is similar in appearance but contains less chert and quartz. Some large springs and caves have been noted in the Eminence Dolomite in the general site area. A spring was reported in the right abutment in the vicinity of the sinkhole noted on earlier photos of the dam.

The soil exposed at the dam site is a dark red-brown, plastic residual clay (CL-CH) characteristically developed on the Potosi Dolomite. The soil contains abundant quartz druse gravel typical of soils formed on the Potosi Dolomite. The soils in this area are mapped as the Captina-Clarksville-Doniphan Soil Association on the Missouri General Soils Map (1979).

The dam is located on the western flank of the Ozark structural dome. The Palmer Fault System is mapped on the Geologic Map of Missouri (1979) approximately 9 mi north of the dam site. The fault system is a complex, branching system of faults trending east-west for approximately 40 mi through Crawford and Washington Counties. Mapped as north side down, the system appears to offset Precambrian and Paleozoic bedrock and is probably Paleozoic in age. This fault system, like other faults in the Ozark region, is not considered seismically active.

The dam is located about 120 miles northwest of the line of epicenters for the very large New Madrid earthquakes which occurred in 1811 and 1812. This location places the dam within Seismic Zone 2, to which the guidelines assign a moderate damage potential. A recurrence of an earthquake of the magnitude of the New Madrid event could cause significant damage at the dam, but a study of this aspect of risk is beyond the scope of this Phase I report.

### SECTION 3 VISUAL INSPECTION

#### 3.1 Findings

- a. **General.** New Viburnum Tailings Dam was inspected on 24 February 1981. Mr John Carter of St Joe Lead Co, accompanied the inspection team throughout the inspection. The results of this inspection tended to indicate the embankment was then in generally fair to good condition.

Subsequent to the inspection, evidence of past sinkhole activity was identified and is further discussed in Section 6, Evaluation of Structural Stability. The term "sinkhole" as used in this report is defined in Section 1.2g.

- b. **Dam.** New Viburnum Tailings Dam is a large dam, approximately 110 ft high. It is still under construction and should be completed by fall 1981. When completed its maximum height will be 130 ft.

New Viburnum Tailings Dam is constructed of silty, fine to medium sand-sized lead tailings (Photo 2), deposited from a cyclone along the crest of the dam (Photo 3). The material appears to be very susceptible to erosion by flowing water or piping. No evidence or record of overtopping was noted during the visual inspection. Some erosion was seen along the upstream slope of the dam. Portions of the dam at the contact with the impounded tailings are deeply eroded by the discharge of fine tailings from the cyclone (Photos 4 and 5). Erosion in the form of gullies was also detected at the top of the downstream slope of the dam, probably caused by a leak in the pipe carrying the tailings slurry to the cyclone (Photo 5). The area downstream of the toe of the dam is covered with a relatively thick layer of tailings, probably transported by water runoff from the downstream slope of the dam and possibly resulting from some internal erosion (piping) related to the past sinkhole activity (Photo 7).

The right portion of the crest of the dam is eroded by wind action which steepens the upper downstream slope of the dam (Photo 8).

Because the dam is still under construction, no erosion protection has been installed on the dam, except for a ditch recently cut on the left abutment to prevent abutment runoff water from flowing onto the downstream face.

Clear water at a rate of approximately 125 gal/min is discharging from a 12-in. diameter drain pipe near the toe of the dam (Photo 9). Clear seepage of about 20 gal/min is also discharging from the toe near the left abutment (Photo 10). It was noticed during our inspection that the area at the toe of the dam was wet and rather soft and showed signs of limited slumping. However, no signs of internal erosion were observed. The extent of these seepage phenomena could not be evaluated accurately, but it was thought that all the water accumulated in the drain downstream of the starter dam was not flowing through the 12-in. diameter pipe but that some water seeped through the embankment toe. The exposed portion of the upstream slope is at an inclination of about 5(H) to 1(V). The downstream slope is also at an inclination of about 5(H) to 1(V).

The vertical and horizontal alignment of the dam crest does not appear to be disturbed or deformed. As the crest on the right portion of the dam is still being raised, a step in the dam crest approximately 1800 ft from the left abutment of the dam is apparent (Overview Photo).

No evidence of detrimental settlement, depressions, sinkholes or cracking was found during the inspection. No animal burrows were detected. The sinkhole which existed in November 1980 was apparently backfilled. No information was obtained on how this was done. Reconnaissance of the area in April 1981 noted renewed development of a depression in the area of the past sinkhole, suggesting internal erosion of the dam is continuing.

There is no vegetation on the dam, except at the downstream toe of the dam where trees are being buried by the deposited tailings (Photo 7).

- c. Appurtenant structures. The spillway that is presently used is located on the right abutment of the dam (Overview Photo). It is a trapezoidal cut, 40 ft wide at the bottom excavated in residual clayey soil (Photo 12). Its bottom is at elevation 1145. It is not lined or vegetated but not anticipated to be subject to severe erosion in the event of flood flows. As the crest of the dam is raised, this spillway will be filled with clay and covered by the tailings embankment.

The final spillway that will be used after the current spillway is filled and the dam is completed to elevation 1180, is located about 1/4 mi south of the dam. It is a trapezoidal cut in residual soil and weathered rock, about 300 ft long and 40 ft wide at its bottom, through the ridge running along the east side of the reservoir (Photo 13). Its crest elevation is 1165; it is not lined nor vegetated and might be subject to significant erosion in the event of flood flows.

- d. Reservoir area. The area surrounding the reservoir is mainly natural wooded hills with 4 or 5(H) to 1(V) slopes; no evidence of unstable slopes was noted. A few hundred feet from the right abutment of the dam, a small earth berm about 500 ft long and 20 ft high (Photo 14) has been constructed to an elevation of 1180 across a topographic depression to provide containment in the event the reservoir surface rises above the elevation of the final spillway.
- e. Downstream channel. The downstream channel flows from the spillway at the right end of the dam into the valley downstream of the dam. Although trees cover the slope of the downstream channel, they do not appear sufficient to obstruct flow during flooding because the slope is rather steep.

### 3.2 Evaluation

The following characteristics were identified during the visual inspection of 24 February 1981. The embankment would erode severely in the event of overtopping. Wind and surface erosion appear to be a potential problem if no protection

is provided. The deep erosion noted on the lower exposed portion of the upstream face of the embankment does not threaten the stability of the dam because this upstream slope is relatively flat. The uncontrolled seepage and associated slumping noted at the downstream toe of the dam is potentially much more serious as it is indicative of continued unsatisfactory drainage at that location. This indication is strongly confirmed by the evidence of past sinkhole activity.

On the basis of the evidence of the past sinkhole, the apparent lack of information on the precise cause of the sinkhole, the lack of documentation on the manner in which the sinkhole was repaired, the indication that uncontrolled seepage is still taking place at the toe of the dam, and possible renewed development of the sinkhole, this dam is considered to be in poor condition. A thorough investigation of these problems is required to better assess the present condition and the probable future safety of this dam.

The very flat slopes of the embankment indicate that, with proper drainage conditions, slope stability per se is not a cause for concern at this dam. The spillways (temporary and permanent) appear to be susceptible to erosion, but not judged sufficient to pose a hazard to the dam, and are not expected to be obstructed during flood flows.

The downstream channels are likely to be eroded during flood conditions, but this erosion is not considered to pose a hazard to the stability of the dam.



## SECTION 4 OPERATIONAL PROCEDURES

### 4.1 Procedures

The dam is still under construction. Procedures in effect have been described in Sections 1.2 and 3.1.

### 4.2 Maintenance of Dam

No maintenance of the dam in the usual sense is being performed as the dam is still under construction. A former sinkhole has apparently been backfilled. No information was obtained on the manner in which the former sinkhole was repaired.

### 4.3 Maintenance of Operating Facilities

There are no facilities requiring mechanical operation at this dam.

### 4.4 Description of Any Warning System in Effect

The visual inspection did not identify any warning system in effect at this dam.

### 4.5 Evaluation

As the dam is still under construction, no operational or maintenance procedures are in effect at this time. Maintenance and inspection procedures, however, will need to be established upon completion of the dam. These should include monitoring the areas of seepage and sinkhole activity to assess the potential for continued internal erosion of the embankment.

The feasibility of a practical warning system should be evaluated to alert downstream residents should potentially hazardous conditions develop at the dam.

## SECTION 5 HYDRAULIC/HYDROLOGIC

### 5.1 Evaluation of Features

- a. Design data. The dam was designed and built by the St Joe Lead Company. Initial construction began in 1971 and is still in progress. The dam height and length used in this study reflect the conditions existing at the time of inspection. Information on the dimensions of the dam, spillway and appurtenant structures was supplied by St Joe Lead Company, or measured during the visual inspection. Other relevant hydrologic data were estimated from the USGS Viburnum East, Missouri, 7.5-minute quadrangle map (1967).
- b. Experience data. No recorded rainfall, runoff, discharge or pool stage data were available for this reservoir or watershed.
- c. Visual observations.
  1. Watershed. The entire watershed is natural woods, forested with mixed hardwoods and softwoods. The area of the reservoir at the current spillway crest elevation is approximately 20 percent of the total drainage area of 1.19 mi<sup>2</sup>.
  2. Reservoir. The reservoir and dam are described in Section 3 of this report and by the maps and photographs enclosed herewith. The principal use of this impoundment is for the storage of lead mine tailings.
  3. Spillways. There are currently two spillways with significant crest elevation differences. The larger, higher, and deeper spillway located away from the dam embankment is to be the final spillway upon the completion of the dam building process. However, the temporary hillside spillway at the southeast end of the existing dam embankment is considered to be the only significant outlet structure at the present time.

- d. **Overtopping potential.** One of the primary considerations in the evaluation of New Viburnum Dam is the assessment of the potential for overtopping and consequent failure by erosion of the embankment. Hydrologic and hydraulic computations indicate that this reservoir and its temporary spillway are capable of handling 100 percent of the Probable Maximum Flood (PMF) without overtopping the dam. The PMF is defined as the flood event that may be expected to occur from the most severe combination of critical meteorologic and hydrologic conditions that are reasonably possible in the region. The guidelines require large dams in the high hazard classification to pass 100 percent of the PMF as the spillway design flood.

The following data are computed for various flood events, assuming no erosion of the temporary spillway.

Precipitation Event	Max. Reservoir W.S. Elev., ft, MSL	Max. Depth Over Dam, ft	Max. Outflow ft <sup>3</sup> /sec	Duration of Overtopping, hrs
1% Prob	1146.8	0	310	0
50% PMF	1149.2	0	1130	0
100% PMF	1152.2	0	2700	0

It should be noted that while the dam embankment will not be overtopped during the PMF, the velocity of discharge in the hillside spillway is approximately 12 ft/sec. Since the spillway is presently unlined, erosion is likely. However, the separation of the spillway from the dam embankment indicates this erosion will not pose a hazard to the stability of the dam.

Input data and output summaries for the hydrologic and hydraulic analyses are presented in Appendix B.

## SECTION 6 STRUCTURAL STABILITY

### 6.1 Evaluation of Structural Stability

- a. Visual observations. Results of the visual inspection of the dam are discussed in Section 3.1.b. As reported in this section, there were no visual indications of severe structural instability of the dam during the 24 February 1981 site inspection.

Uncontrolled seepage at the downstream toe of the dam did not appear at that time to be seriously detrimental since no evidence of internal erosion was found and only small slumping was identified. Coupled with the evidence of the existence of a sinkhole only four months before the inspection and the apparent renewal of sinkhole development several months later, however, this seepage becomes of much more concern, as it indicates that there is a potential for piping (internal erosion) of the dam. The structural stability of the dam can be seriously affected if piping occurs at the toe or under the downstream slope of the dam. It is particularly important to note that the elevations of the present and future spillways dictate that the operating level of the reservoir will in the future be at least 20 ft higher than any condition experienced by this embankment to date. This could have very serious seepage and stability consequences and should be a subject of further study.

Large erosion features on the upstream face caused by the discharge of the fine tailings dumped into the reservoir from the cyclone do not appear to endanger the overall stability or safety of the dam. However they do confirm that the material used to build the embankment is in fact highly erodible. Uncontrolled surface or internal erosion could endanger the structural stability of the dam.

- b. Design and construction data. Information on the design and construction of New Viburnum Tailings Dam was obtained from plans and drawings supplied by St Joe Lead Co (Appendix C) and through interviews with Mr John Kennedy and Mr John Carter. Construction procedures are presented in Sections 1.2 and 2.2.

Seepage and stability analyses comparable to the requirements of the "Recommended Guidelines for Safety Inspection of Dams" were not on record. This is considered a deficiency which should be rectified.

- c. Operating records. No operating records were available.
- d. Post construction changes. As the dam is still under construction, there are no post construction changes.
- e. Seismic stability. The dam is in Seismic Zone 2, to which the guidelines assign a moderate damage potential. Since no static stability analyses are available for review of the dam in its present configuration, the seismic stability cannot be evaluated. However, as the embankment consists of relatively loose, fine granular material, it is expected that substantial deformation of the embankment could occur during a severe seismic event. The extent of this deformation will be largely controlled by the position of the phreatic surface in the dam. It is known from observations at other similar dams that the phreatic surface can be high during construction, especially near the location of the cyclones which discharge a large volume of water for long periods of time on the crest of the dam. After construction, provided the downstream drains continue to operate adequately, the phreatic surface is expected to drop, making the embankment less susceptible to liquefaction during a seismic event. Monitoring of the position of the phreatic surface in this embankment is highly desirable and would be necessary for the stability analyses required by the guidelines.

## SECTION 7

### ASSESSMENT/REMEDIAL MEASURES

#### 7.1 Dam Assessment

- a. **Safety.** Based on the visual inspection alone, New Viburnum Tailings Dam was initially judged to be in fair to good condition. Uncontrolled seepage and limited slumping at the toe of the dam were the reason for this assessment. As discovered after the inspection, the evidence of a sinkhole which existed about four months prior to our field visit, and the evidence of renewed sinkhole development following the inspection, indicates that this dam must be considered to be in poor condition until a more thorough investigation is made of the potential for piping.

Hydraulic and hydrologic analyses indicate that the reservoir and the present spillway are capable of handling 100 percent of the Probable Maximum Flood (PMF) without overtopping the dam.

Seepage and stability analyses comparable to the "Recommended Guidelines for Safety Inspection of Dams" are not on record, which is considered a deficiency.

- b. **Adequacy of information.** The visual inspection and previous records provided a reasonable base of information for the conclusions and recommendations presented in this Phase I report.

The lack of design documents such as static and seismic stability analyses and a seepage analysis for the dam as recommended in the guidelines precludes an evaluation of the static or seismic stability of the dam.

- c. **Urgency.** The deficiencies described in this report could affect the safety of the dam. Remedial measures that should be initiated immediately or without undue delay are addressed in Section 7.2b.

- d. **Necessity for Phase II.** In accordance with the "Recommended Guidelines for Safety Inspection of Dams," the subject investigation is a minimum study. This study revealed that additional in-depth investigations are needed to complete the assessment of the safety of the dam. Those investigations which should be performed immediately are described in Section 7.2b. It is our understanding from discussions with the St Louis District that any additional investigations are the responsibility of the owner.

## 7.2 **Remedial Measures**

- a. **Alternatives.** There are several general options which may be considered to reduce the possibility of dam failure or to diminish the harmful consequences of such a failure. Some of these general options are:
1. Remove the dam, or breach it to prevent storage of water;
  2. Purchase downstream land that would be adversely impacted by dam failure and restrict human occupancy;
  3. Provide a highly reliable flood warning system (generally does not prevent damage but diminishes the chances for loss of life).
- b. **Recommendations.** Based on our inspection of New Viburnum Tailings Dam it is recommended that the following steps be taken as a minimum.
1. A thorough investigation of the sinkhole conditions at the toe of the dam should be conducted to evaluate the extent of the piping phenomena. This investigation should include all prior sinkhole activity events, assessment of their causes and evaluation of remedial work. Particular attention should be directed to the position of the phreatic surface in the downstream slope and changes in this surface resulting from variations in cyclone operations, reservoir level and rainfall. Furthermore, assessment should be made of the probable consequence of raising the reservoir elevation by 20 ft upon the closure of the present temporary spillway.

2. During and after the construction period of the dam, periodic inspections of the embankment should be made to detect erosion due to runoff, rainfall, leakage in the piping system of the cyclone, spring flow, or seeping water.

3. A program of erosion protection for the surface of the embankment should be prepared.

4. Seepage and stability analyses comparable to the requirements of the "Recommended Guidelines for Safety Inspection of Dams" should be made for appropriate loading conditions, including earthquake loads, and made a matter of record. These analyses should include consideration of the variable position of the phreatic surface.

5. The feasibility of a practical and reliable warning system should be evaluated to alert downstream residents and traffic in the event hazardous conditions develop at this dam during periods of flooding.

All remedial measures should be performed under the guidance of an engineer experienced in the design and construction of tailings dams.

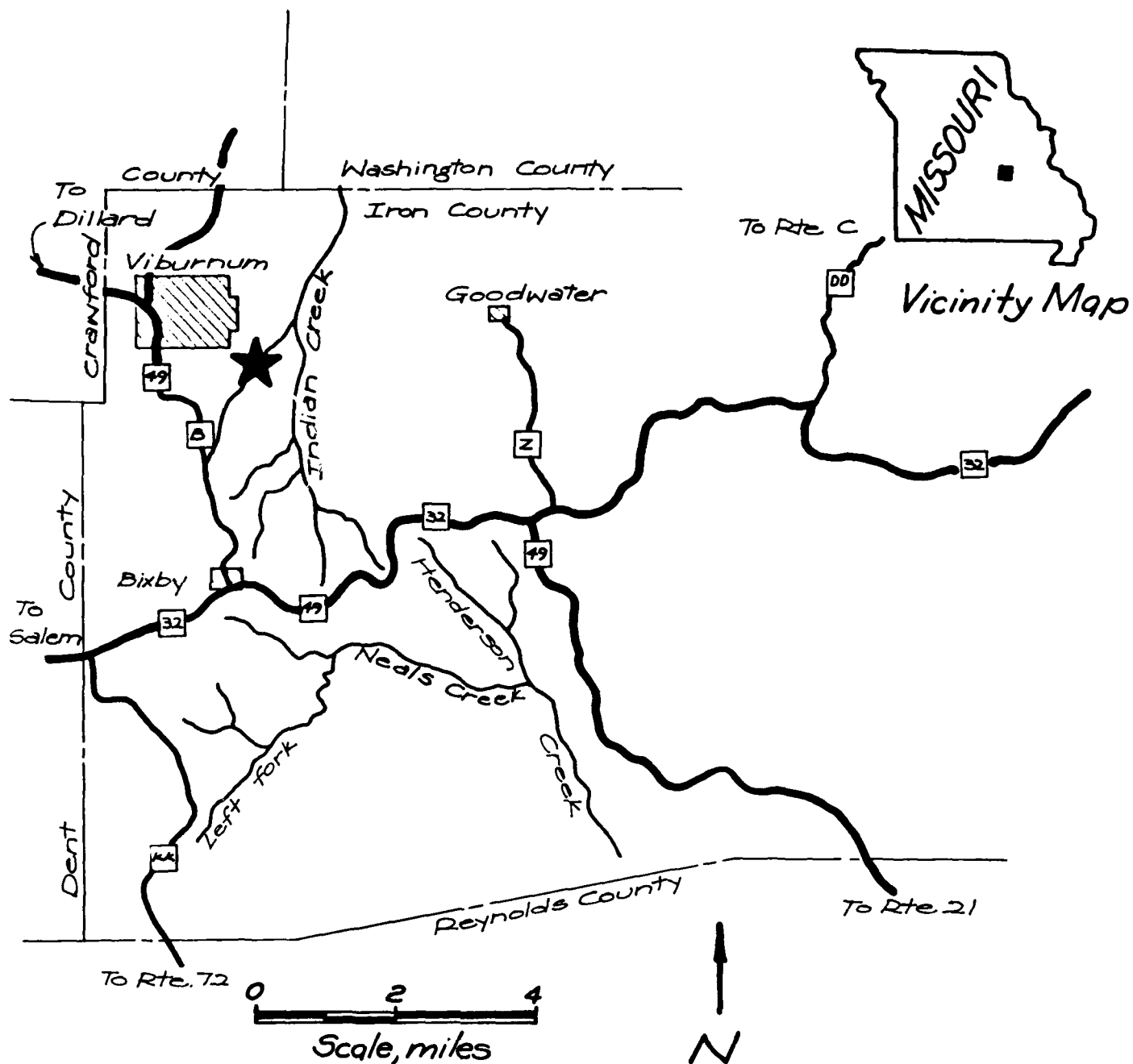
Measures concerning the evaluation and periodic inspection of potential piping at the toe of the dam should be performed immediately. Other studies should be done without undue delay.

- c. **O & M procedures.** To provide adequate maintenance of this facility once it is completed, it is recommended that a program of periodic inspections be implemented as soon as practical. The purpose of this program should be to identify maintenance requirements. The inspection and maintenance should be performed under the guidance of an engineer experienced in the design and construction of tailings dams. Records of the inspection and maintenance performed should be kept.



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- US Department of Commerce, US Weather Bureau, 1956, "Seasonal Variation of the Probable Maximum Precipitation East of the 105th Meridian for Areas from 10 to 1,000 Square Miles and Durations of 6, 12, 24 and 48 Hours," Hydrometeorological Report No. 33.



### Legend

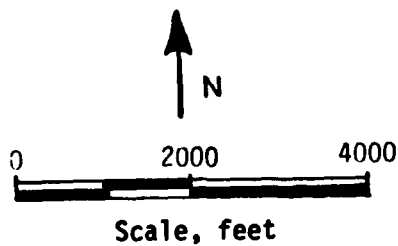
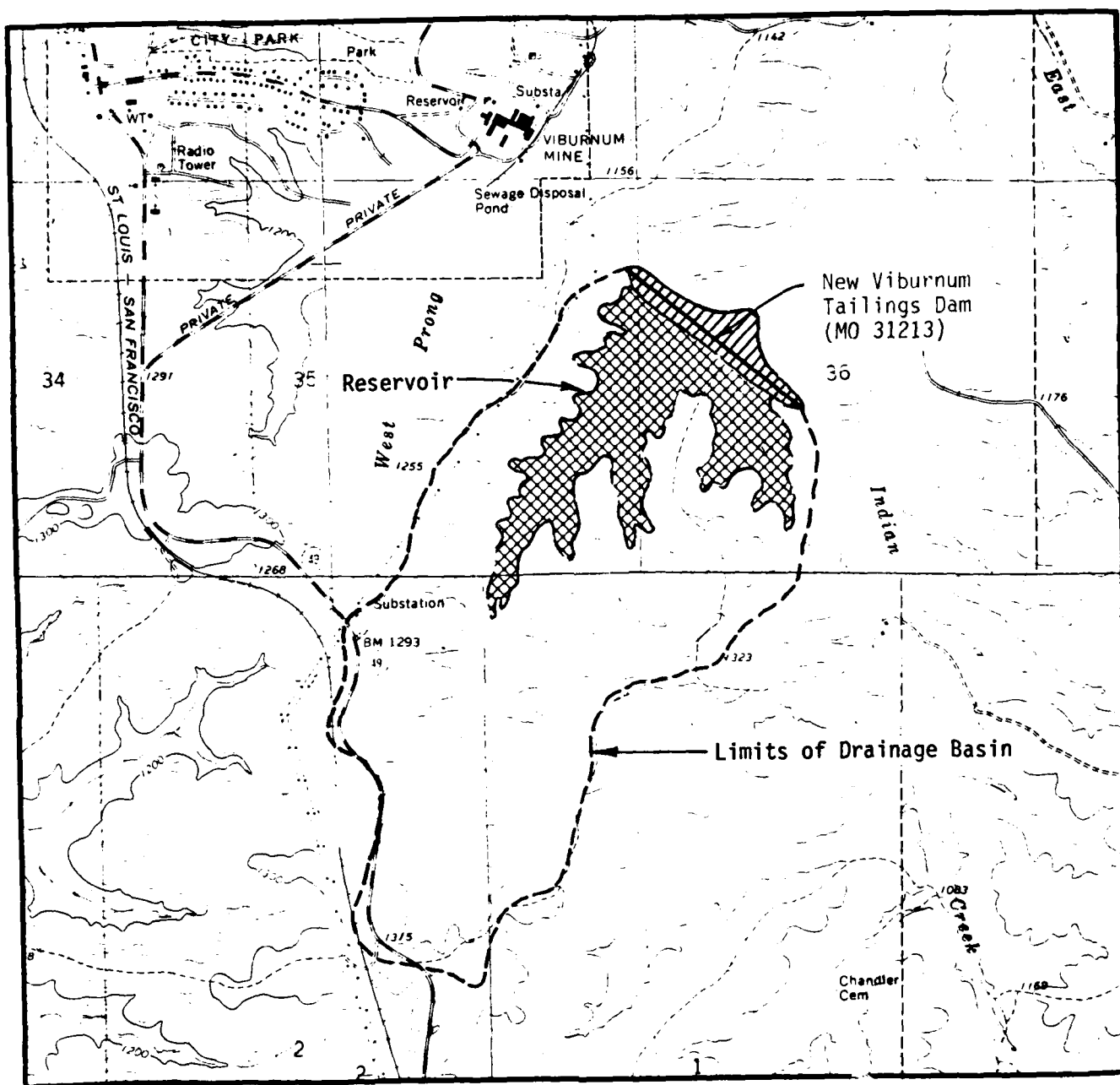
- County Line
- State highway and Route No.
- River or Creek
- City or Town
- Project location

### SITE LOCATION MAP

NEW VIBURNUM  
TAILINGS DAM

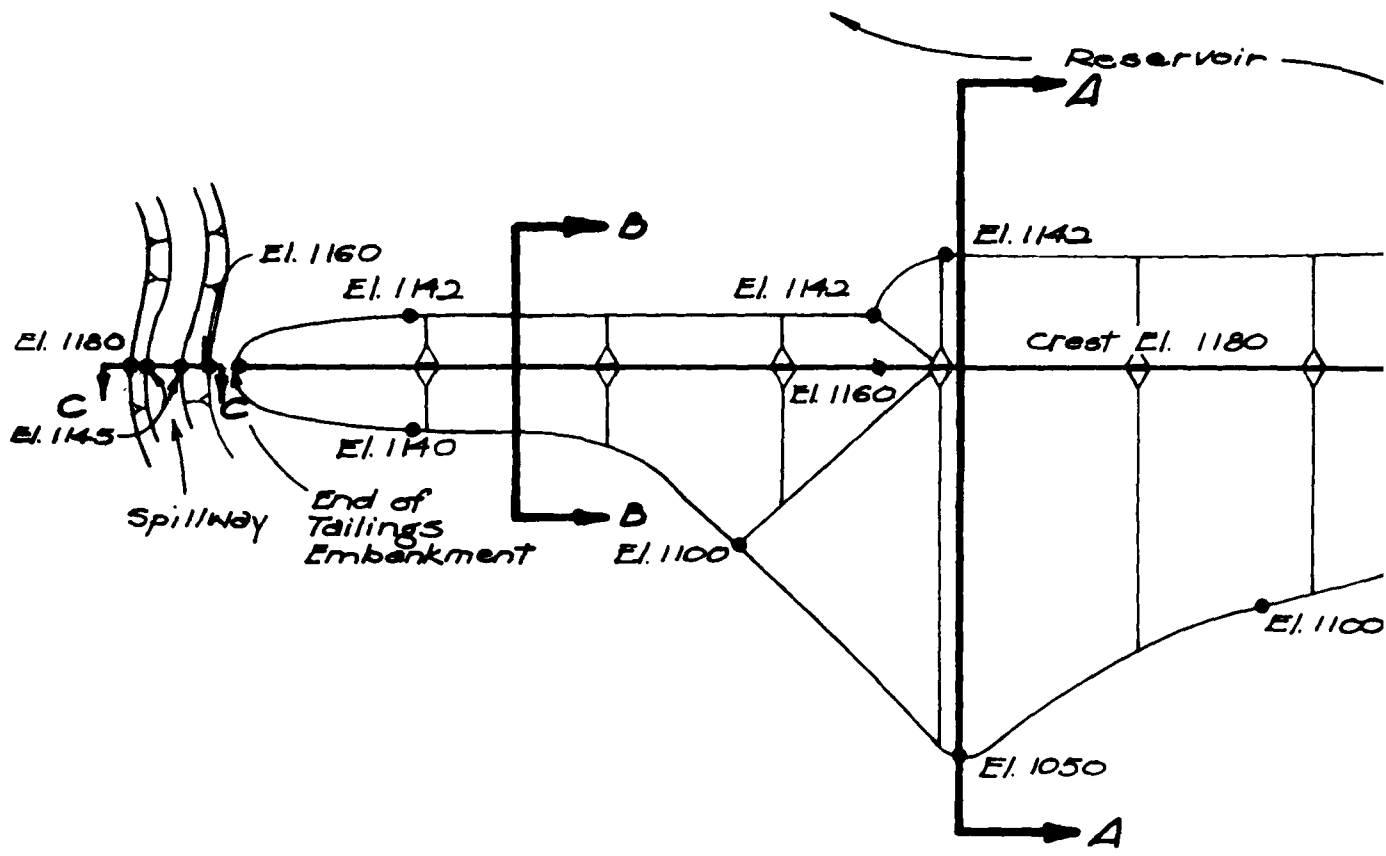
MO 31231

Fig. 1

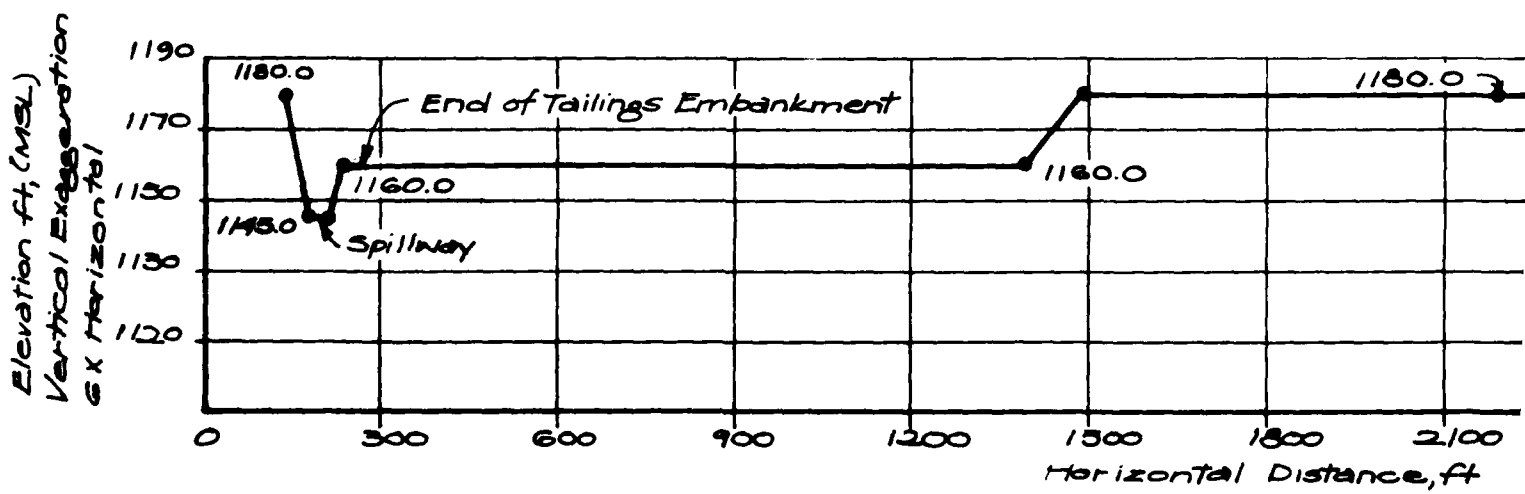


Note:  
 1. Topography from USGS Viburnum East and Viburnum West 7.5-minute quadrangle maps (1967).

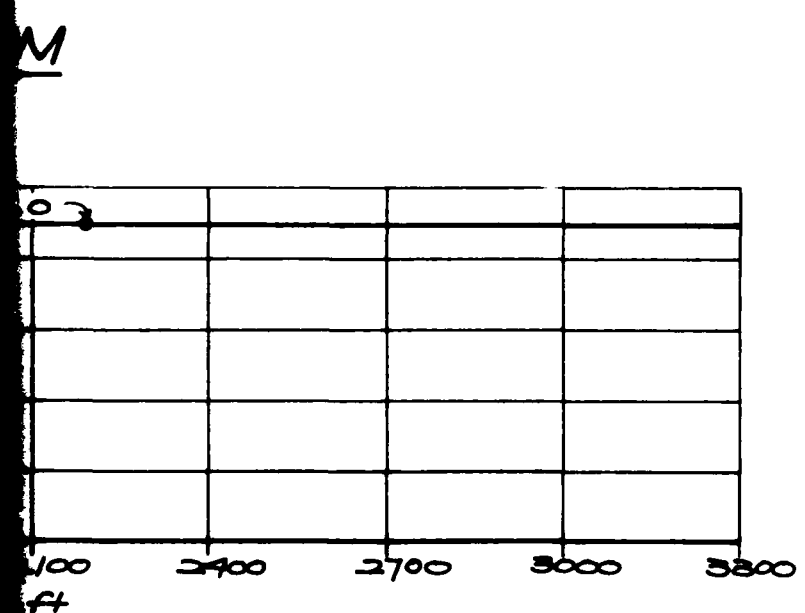
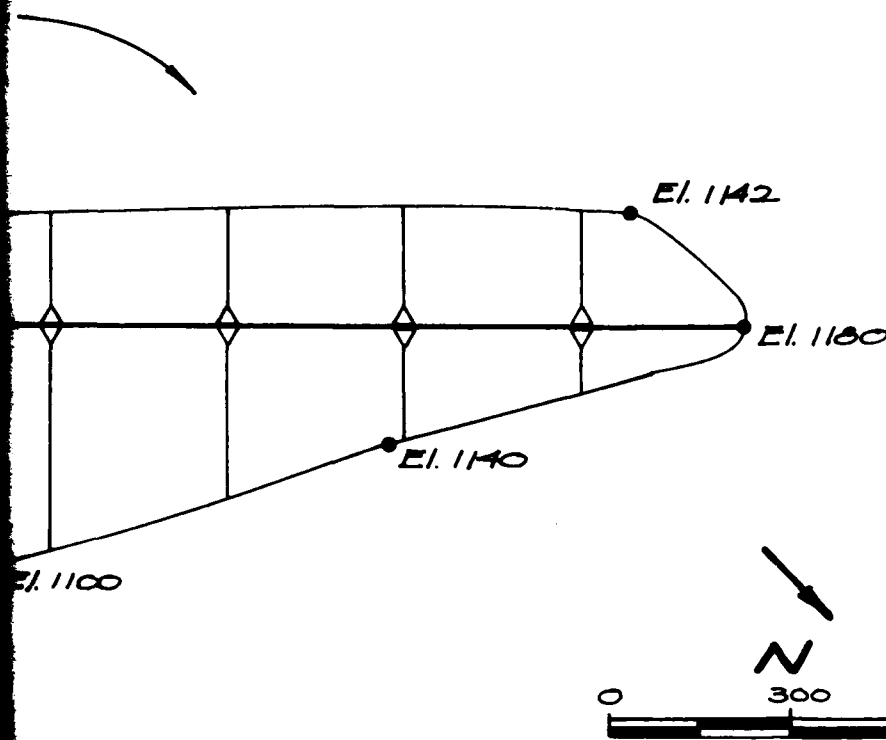
<b>DRAINAGE BASIN AND SITE TOPOGRAPHY</b>	
<b>NEW VIBURNUM TAILINGS DAM</b>	
MO 31231	Fig. 2



PLAN OF DAM

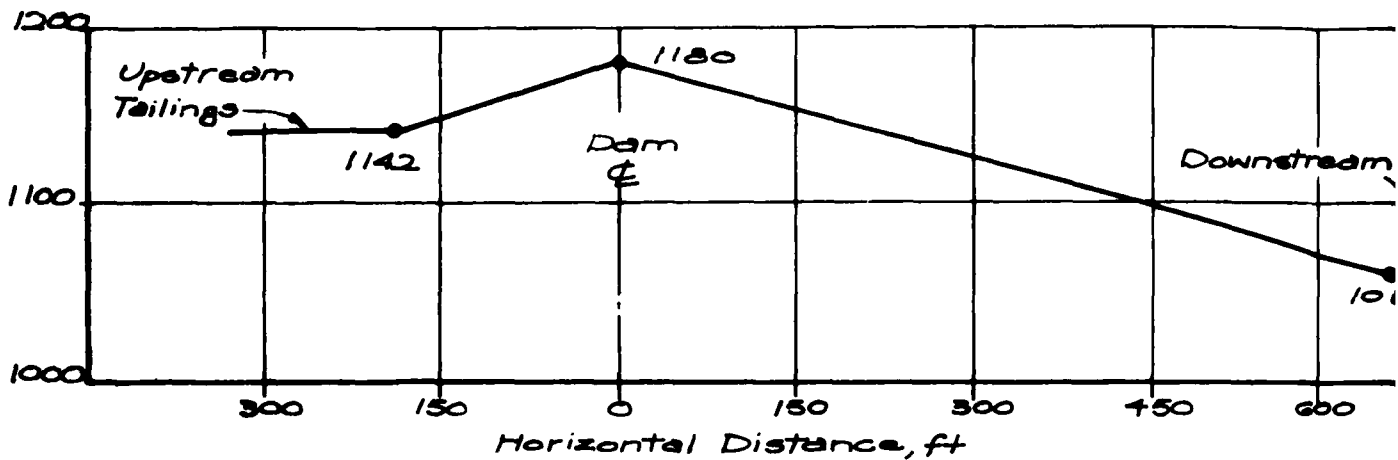


DAM PROFILE



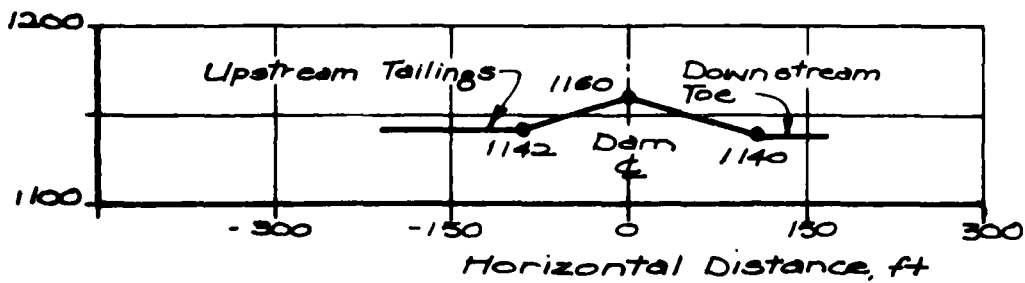
<b>PLAN AND PROFILE OF DAM</b>	
NEW VIBURNUM TAILINGS DAM	
MO 31231	Fig. 2-4

Elevation ft. (± 5')  
Vertical Exaggeration  
1.5 X Horizontal

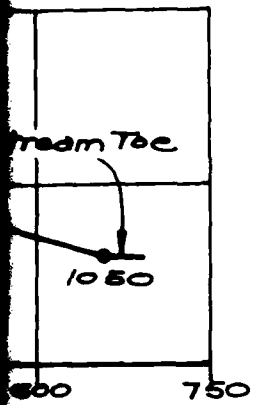


**SECTION A-A**  
Maximum Dam Section

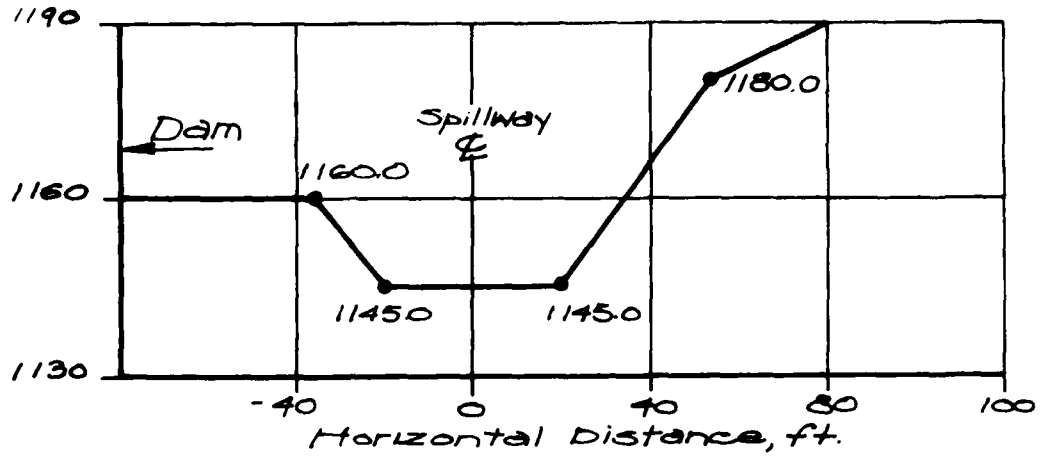
Elevation ft. (MSL)  
Vertical Exaggeration  
1.5 X Horizontal



**SECTION B-B**  
Dam Section



Elevation ft. (MSL)  
Vertical Exaggeration  
1.25 X Horizontal



SECTION C-C  
Spillway Section

**DAM AND SPILLWAY  
CROSS SECTIONS**

NEW YORK  
TALMAGE DAM

MO 31231

Fig. 6-6

## Legend

Smithville Formation  
Powell Dolomite  
Cotter Dolomite  
Jefferson City Dolomite

Roubidoux Formation

Gasconade Dolomite  
Gunter Sandstone Member

Eminence Dolomite

Potosi Dolomite

Derby-Doerun Dolomite

Davis Formation

Bonnerterre Formation  
Whetstone Creek Member  
Sullivan Siltstone Member

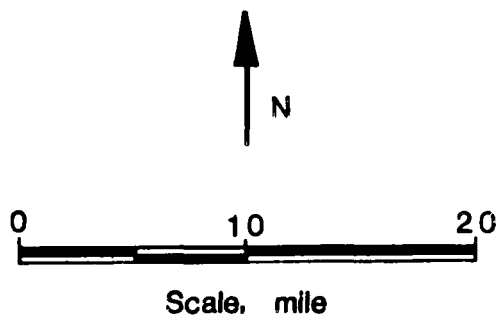
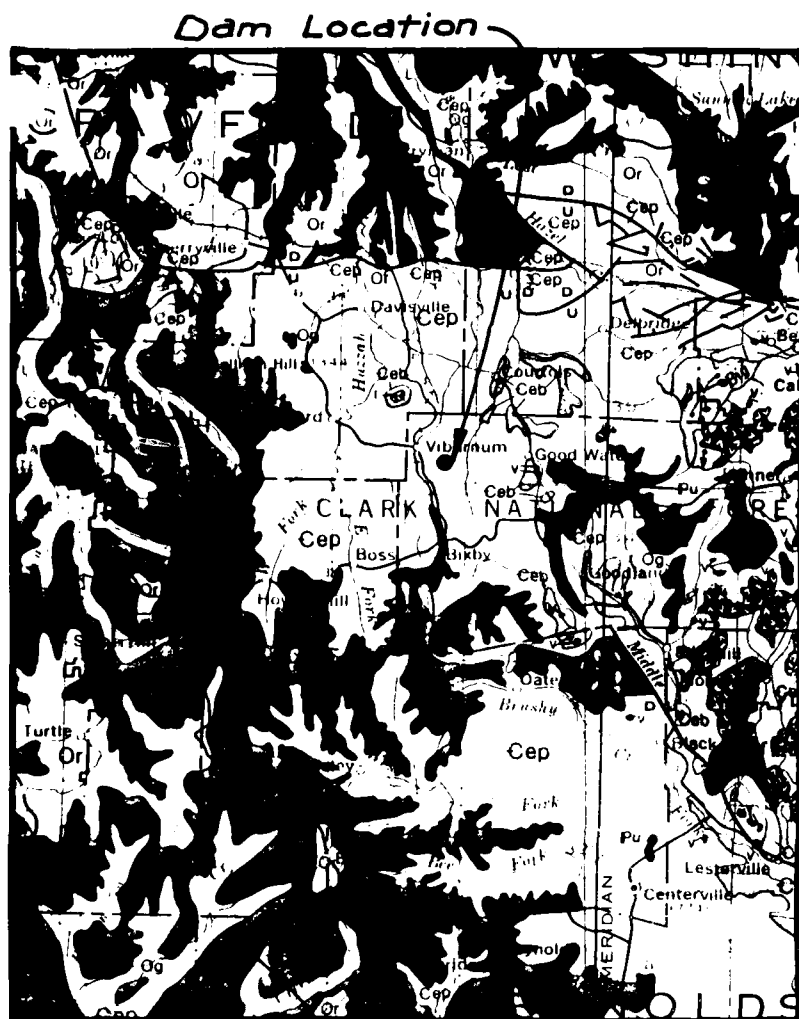
Reagan Sandstone  
(subsurface, western Missouri)

Lamotte Sandstone

Diabase (dikes and sills)

St. Francois Mountains Intrusive Suite

St. Francois Mountains Volcanic Supergroup

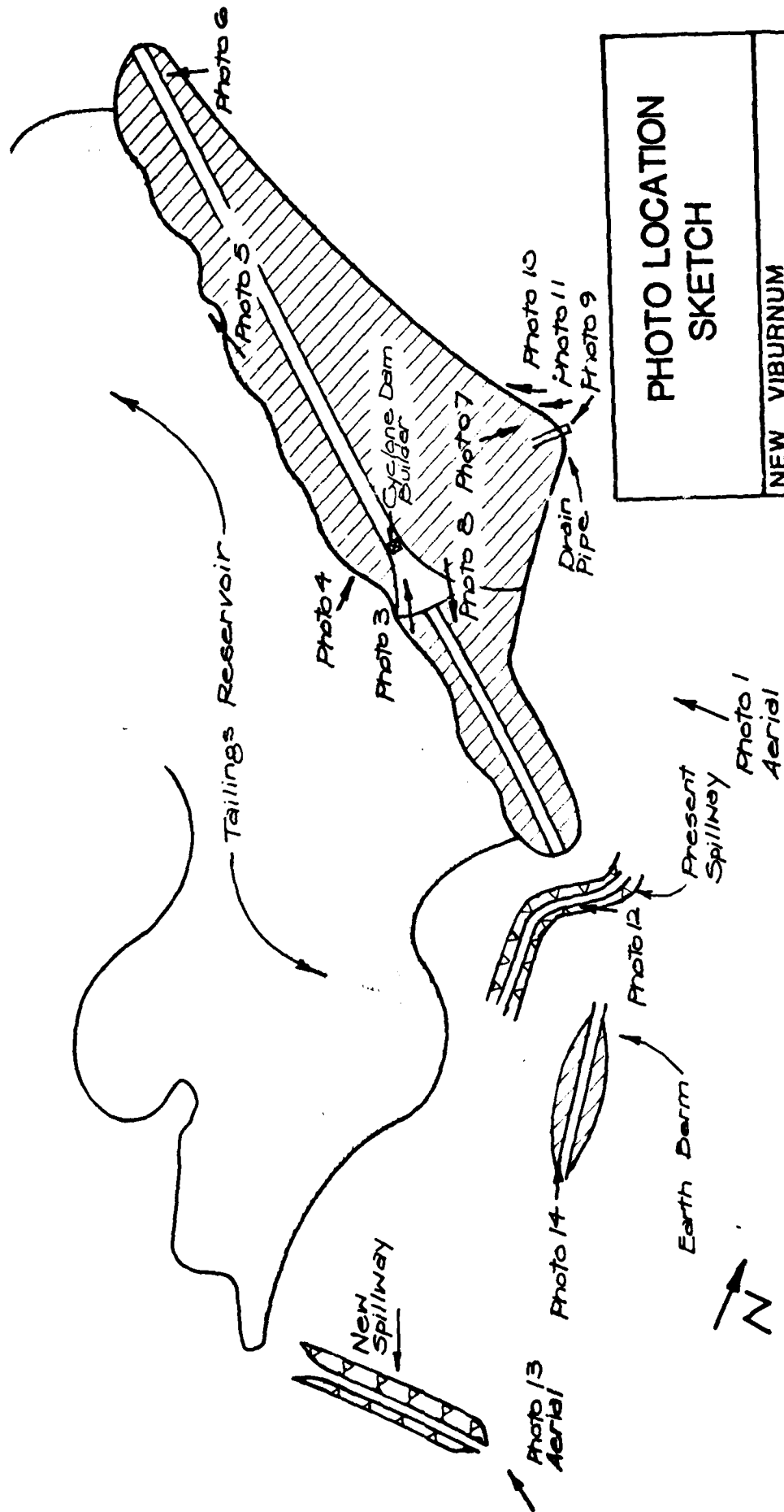


REGIONAL GEOLOGIC MAP	
NEW VIBURNUM TAILINGS DAM	
MO 31231	Fig. 4



**APPENDIX A**

Photographs

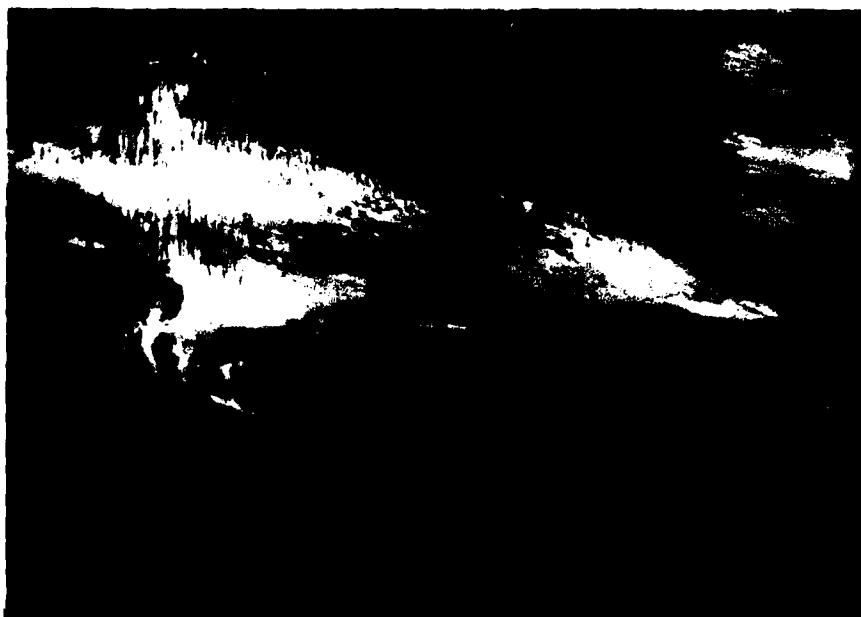


# PHOTO LOCATION SKETCH

NEW VIBURNUM  
TAILINGS DAM

MO 31231

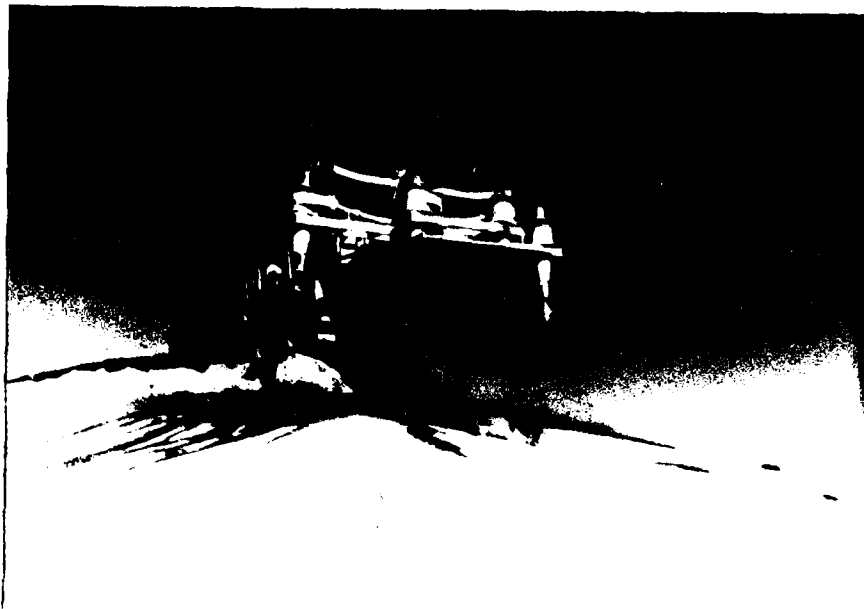
Fig. A-1



1. View of the downstream face of New Viburnum Tailings Dam near the right abutment. Note the present spillway on the left of the photograph and the former spillway under the low elevation tailings embankment.



2. Close-up photograph of tailings used for the construction of the dam embankment.



3. Cyclone installed on the crest of the embankment spreading slurries of the coarse-grained fraction used for the construction of the embankment.



4. Discharge pipe from the cyclone along the upstream face of the embankment.



5. Erosion of the upstream face of the embankment from previous discharge of fine tailings slurries into the reservoir. Looking northwest.



6. Erosion in the form of gullies at the top of the downstream face of the embankment near the left abutment. Note the pipe running along the crest and carrying tailings slurries to the cyclone.



7. Downstream toe of the embankment. Looking northeast. Note the tailings up to the settling pond in the background and the buried trees. Also note seepage erosion area at the immediate toe of the dam.



8. Aeolian dune face along downstream face of the right end of the embankment. Looking southeast.



9. Drain pipe at the toe of the dam near the right abutment.



10. Seepage at the toe of the downstream face of the embankment near the left abutment.



11. Seepage erosion at downstream toe of the embankment.



12. Present spillway. Looking west. Dam is out of picture to the right.





13. Aerial view of the dam and reservoir. Looking northwest.  
 Note the final spillway at the bottom left of the photo.



14. Earth berm along the ridge top on the right abutment  
 of the dam. Looking north.



15. Aerial view of New Viburnum Tailings Dam in November 1980. Note sinkhole at toe of dam. Also note grayish tailings downstream of sinkhole that could be the result of recent internal erosion associated with the sinkhole.

## **APPENDIX B**

Hydraulic/Hydrologic Data and Analyses

## APPENDIX B

### Hydraulic/Hydrologic Data and Analyses

#### B.1 Procedures

- a. General. The hydraulic/hydrologic analyses were performed using the "HEC-1, Dam Safety Version (1 Apr 80)" computer program. The inflow hydrographs were developed for various precipitation events by applying them to a synthetic unit hydrograph. The inflow hydrographs were subsequently routed through the reservoir and appurtenant structures by the modified Puls reservoir routing option.
- b. Precipitation events. The Probable Maximum Precipitation (PMP) and the 1 and 10 percent probability-of-occurrence events were used in the analyses. The total rainfall and corresponding distributions for the 1 and 10 percent probability events were provided by the St. Louis District, Corps of Engineers. The Probable Maximum Precipitation was determined from regional curves prepared by the US Weather Bureau (Hydrometeorological Report Number 33, 1956).
- c. Unit hydrograph. The Soil Conservation Services (SCS) Dimensionless Unit Hydrograph method (SCS, 1971, Hydrology: National Engineering Handbook, Section 4) was used in the analysis. This method was selected because of its simplicity, applicability to drainage areas less than 10 mi<sup>2</sup>, and its easy availability within the HEC-1 computer program.

The watershed lag time was computed using the SCS "curve number method" by an empirical relationship as follows:

$$L = \frac{\ell^{0.8} (s+1)^{0.7}}{1900 Y^{0.5}} \quad (\text{Equation 15-4})$$

where:  $L$  = lag in hours

$\ell$  = hydraulic length of the watershed in feet = 5400

$$s = \frac{1000}{CN} - 10 = 2.987$$

$CN$  = AMC II hydrologic soil curve number as indicated in Section B.2e.

$Y$  = average watershed land slope in percent = 4.1.

This empirical relationship accounts for the soil cover, average watershed slope and hydraulic length.

With the lag time thus computed, another empirical relationship is used to compute the time of concentration as follows:

$$T_c = \frac{L}{0.6} \quad (\text{Equation 15-3})$$

where:  $T_c$  = time of concentration in hours

$L$  = lag in hours.

Subsequent to the computation of the time of concentration, the unit hydrograph duration was estimated utilizing the following relationship:

$$\Delta D = 0.133T_c \quad (\text{Equation 16-12})$$

where:  $\Delta D$  = duration of unit excess rainfall  
 $T_c$  = time of concentration in hours.

The final interval was selected to provide at least three discharge ordinates prior to the peak discharge ordinate of the unit hydrograph. For this dam, a time interval of 10 minutes was used.

- d. Infiltration losses. The infiltration losses were computed by the HEC-1 computer program internally using the SCS curve number method. The curve numbers were established taking into consideration the variables of: (a) antecedent moisture condition, (b) hydrologic soil group classification, (c) degree of development, (d) vegetative cover and (e) present land usage in the watershed.

Antecedent moisture condition III (AMC III) was used for the PMF events and AMC II was used for the 1 and 10 percent probability events, in accordance with the guidelines. The remaining variables are defined in the SCS procedure and judgements in their selection were made on the basis of visual field inspection.

- e. Starting elevations. Reservoir starting water surface elevations for this dam were set as follows:

- (1) 1 and 10 percent probability events - spillway crest elevation of 1145 ft.
- (2) Probable Maximum Storm - spillway crest elevation of 1145 ft

Because this is a tailings dam which has no outlet structure the starting water surface elevations for all floods were set at the crest elevation of the dam spillway.

- f. Spillway Rating Curve. The HEC-2 computer program was used to compute the spillway rating curve using spillway channel cross section and conveyance characteristics.

## B.2 Pertinent Data

- a. Drainage area.  $1.19 \text{ m}^2$
- b. Storm duration. A unit hydrograph was developed by the SCS method option of HEC-1 program. The design storm of 48 hours duration was divided into 10-minute intervals in order to develop the inflow hydrograph.

- c. Lag time. 0.66 hours
- d. Hydrologic soil group. C/D
- e. SCS curve numbers.
  - 1. For PMF- AMC III - Curve Number 89
  - 2. For 1 and 10 percent probability-of-occurrence events - AMC II - Curve Number 77
- f. Storage. Elevation-area data were developed by planimetering areas at various elevation contours on the USGS Viburnum East (1967) 7.5 minute quadrangle map. The data were entered on the \$A and \$E cards so that the HEC-1 program could compute storage volumes.
- g. Outflow over dam crest. As the profile of the dam crest is irregular, flow over the crest was computed according to the "Flow Over Non-Level Dam Crest" supplement to the HEC-1 User's Manual. The crest length-elevation data and hydraulic constants were entered on the \$D, \$L, and \$V cards.
- h. Outflow capacity. The spillway rating curve was developed from the cross section data of the spillway using the HEC-2 backwater program. The results of the above were entered on the Y4 and Y5 cards of the HEC-1 program.
- i. Reservoir elevations. For the 50 and 100 percent of the PMF events, the starting reservoir elevation was 1145.0 ft, the spillway crest elevation. For the 1 and 10 percent probability-of-occurrence events, the starting reservoir elevation was 1145.0 the spillway crest elevation.

### B.3 Results

The results of the analyses as well as the input values to the HEC-1 program follow in this Appendix. Only the results summaries are included, not the intermediate output. Complete copies of the HEC-1 output are available in the project files.



... VINEO 13.28.12.

NEW VIBURNUM DAM, NO. 31231, IRON COUNTY, MISSOURI.  
WOODWARD-CLYDE CONSULTANTS, HOUSTON JOB-00C224.  
PROBABLE MAXIMUM FLOODS.

~~100-392616-1C27-10N~~

NO	MHR	NNIN	IDAY	IHR	IMIN	METRC	IPLT	IPRT	NSTAN
286	0	10	0	0	0	0	0	0	0
			SUPER	NAT	CROFT	TRACE			

.. NPLAN= 1 NRTIO= 2 LRTIO= 1

~~SUB-AREA-RUNOFF-COMPUTATION~~

**NEW VIBURNUM TAILINGS DAM INFLOW COMPUTATIONS, PMF.**

ISTAQ	ICOMP	IECON	ITYPE	JPLY	JPRY	INAME	ISTAGE	IAUTO
INFLOW	0	0	0	0	0	1	0	0

HYDROGRAPH DATA

HWYDGT	TUNG	TAREA	SWAP	TRSDA	TRSPC	RATIO	TSHOW	ISAME	LOCAL
1	1.19	0.00	1.19	1.00	0.000	0	0	0	0

**PRECIP DATA**

SPFC	PWS	86	812	824	840	872	896
8.00	26.00	102.00	120.00	130.00	140.00	0.00	0.00

**1-800-4-A-FOAM**

	STARR	DLTKR	RYIOL	ERAIN	STAKS	RYIOK	STRYL	CNSTL	ALSMX	RYTMP
ELCROPT	0	0.00	1.00	0.00	0.00	1.00	-1.00	-99.00	0.00	.20

CIRQUE NO 7 -89.00 #SYNFS9 = -1.00 EFFECT CM = 89.00

~~UNIT HYDROGRAPH DATA~~  
TC= 0.00 LAG= .66

**Definition 9.11**

```
STAT90= -1.00  ORCSN= -.05  RTIOR= 5.00
```

UNIT	WROUGHT IRON	22	END OF PERIOD	INITIALS	PC	7.00	MOVING	LAGE	00	WTL	1.00
94.	299.	599.	763.	755.	676.	461.	305.	211.	190.		
103.	72.	50.	34.	24.	17.	11.	9.	6.	4.		

Output Summary  
Various PMF Events  
New Viburnum Dam  
MO 31231  
BS





Output Summary  
Various PMF  
New Viburnum  
MO 31231  
B7 Events  
Dam

1.01	9.20	96	.01	.00	.01	9.	1.02	9.20	200	.13	.13	.00	577.
1.01	9.30	57	.01	.00	.01	10.	1.02	9.30	201	.13	.13	.00	582.
1.01	9.40	58	.01	.00	.01	10.	1.02	9.40	202	.13	.13	.00	583.
1.01	9.50	59	.01	.00	.01	10.	1.02	9.50	203	.13	.13	.00	584.
1.01	10.00	60	.01	.00	.01	11.	1.02	10.00	204	.13	.13	.00	585.
1.01	10.10	61	.01	.00	.01	11.	1.02	10.10	205	.13	.13	.00	586.
1.01	10.20	62	.01	.00	.01	12.	1.02	10.20	206	.13	.13	.00	587.
1.01	10.30	63	.01	.00	.01	12.	1.02	10.30	207	.13	.13	.00	588.
1.01	10.40	64	.01	.00	.01	13.	1.02	10.40	208	.13	.13	.00	589.
1.01	10.50	65	.01	.00	.01	13.	1.02	10.50	209	.13	.13	.00	590.
1.01	11.00	66	.01	.00	.01	14.	1.02	11.00	210	.13	.13	.00	591.
1.01	11.10	67	.01	.00	.01	14.	1.02	11.10	211	.13	.13	.00	592.
1.01	11.20	68	.01	.00	.01	14.	1.02	11.20	212	.13	.13	.00	593.
1.01	11.30	69	.01	.00	.01	15.	1.02	11.30	213	.13	.13	.00	594.
1.01	11.40	70	.01	.00	.01	15.	1.02	11.40	214	.13	.13	.00	595.
1.01	11.50	71	.01	.00	.01	16.	1.02	11.50	215	.13	.13	.00	596.
1.01	12.00	72	.01	.00	.01	16.	1.02	12.00	216	.13	.13	.00	597.
1.01	12.10	73	.03	.01	.02	18.	1.02	12.10	217	.44	.44	.01	618.
1.01	12.20	74	.03	.02	.02	21.	1.02	12.20	218	.44	.44	.01	619.
1.01	12.30	75	.03	.02	.02	28.	1.02	12.30	219	.44	.44	.00	620.
1.01	12.40	76	.03	.02	.02	37.	1.02	12.40	220	.44	.44	.00	621.
1.01	12.50	77	.03	.02	.02	40.	1.02	12.50	221	.44	.44	.00	622.
1.01	13.00	78	.03	.02	.02	55.	1.02	13.00	222	.44	.44	.00	623.
1.01	13.10	79	.04	.02	.02	62.	1.02	13.10	223	.53	.53	.00	624.
1.01	13.20	80	.04	.02	.02	70.	1.02	13.20	224	.53	.53	.00	625.
1.01	13.30	81	.04	.02	.02	77.	1.02	13.30	225	.53	.53	.00	626.
1.01	13.40	82	.04	.02	.02	85.	1.02	13.40	226	.53	.53	.00	627.
1.01	13.50	83	.04	.02	.02	92.	1.02	13.50	227	.53	.53	.00	628.
1.01	14.00	84	.04	.03	.01	98.	1.02	14.00	228	.53	.53	.00	629.
1.01	14.10	85	.05	.03	.02	105.	1.02	14.10	229	.66	.66	.00	630.
1.01	14.20	86	.05	.03	.02	111.	1.02	14.20	230	.66	.66	.00	631.
1.01	14.30	87	.05	.04	.02	120.	1.02	14.30	231	.66	.66	.00	632.
1.01	14.40	88	.05	.04	.01	129.	1.02	14.40	232	.66	.66	.00	633.
1.01	14.50	89	.05	.04	.01	136.	1.02	14.50	233	.66	.66	.00	634.
1.01	15.00	90	.05	.04	.01	146.	1.02	15.00	234	.66	.66	.00	635.
1.01	15.10	91	.05	.03	.01	153.	1.02	15.10	235	.60	.60	.00	636.
1.01	15.20	92	.05	.03	.02	160.	1.02	15.20	236	.60	.60	.00	637.
1.01	15.30	93	.14	.11	.03	174.	1.02	15.30	237	1.81	1.81	.00	638.
1.01	15.40	94	.35	.29	.06	222.	1.02	15.40	238	4.53	4.53	.01	639.
1.01	15.50	95	.10	.06	.02	309.	1.02	15.50	239	1.31	1.31	.00	640.
1.01	16.00	96	.06	.04	.01	404.	1.02	16.00	240	.81	.81	.00	641.
1.01	16.10	97	.05	.04	.01	461.	1.02	16.10	241	.62	.62	.00	642.
1.01	16.20	98	.05	.04	.02	461.	1.02	16.20	242	.62	.62	.00	643.
1.01	16.30	99	.05	.04	.01	421.	1.02	16.30	243	.62	.62	.00	644.
1.01	16.40	100	.05	.04	.01	362.	1.02	16.40	244	.62	.62	.00	645.
1.01	16.50	101	.05	.04	.01	308.	1.02	16.50	245	.62	.62	.00	646.
1.01	17.00	102	.05	.04	.01	272.	1.02	17.00	246	.62	.62	.00	647.
1.01	17.10	103	.04	.03	.00	247.	1.02	17.10	247	.49	.49	.00	648.
1.01	17.20	104	.04	.03	.00	211.	1.02	17.20	248	.49	.49	.00	649.
1.01	17.30	105	.04	.03	.00	196.	1.02	17.30	249	.49	.49	.00	650.
1.01	17.40	106	.04	.03	.00	175.	1.02	17.40	250	.49	.49	.00	651.
1.01	17.50	107	.04	.03	.00	165.	1.02	17.50	251	.49	.49	.00	652.
1.01	18.00	108	.04	.03	.00	152.	1.02	18.00	252	.49	.49	.00	653.
1.01	18.10	109	.00	.00	.00	131.	1.02	18.10	253	.04	.04	.00	654.
1.01	18.20	110	.00	.00	.00	106.	1.02	18.20	254	.04	.04	.00	655.
1.01	18.30	111	.00	.00	.00	81.	1.02	18.30	255	.04	.04	.00	656.
1.01	18.40	112	.00	.00	.00	60.	1.02	18.40	256	.04	.04	.00	657.
1.01	18.50	113	.00	.00	.00	45.	1.02	18.50	257	.04	.04	.00	658.
1.01	19.00	114	.00	.00	.00	45.	1.02	19.00	258	.04	.04	.00	659.
1.01	19.10	115	.00	.00	.00	45.	1.02	19.10	259	.04	.04	.00	660.

Output Summary  
Various PMR Events  
New Viburnum Dam  
MO 31231  
B8

[illegible]

## HYDROGRAPH AT STAINFLOW FOR PLAN 1, RYIO 1

[illegible]

FLOW AND STORAGE (END OF PERIOD) SUMMARY FOR MULTIPLE PLAN-RATIO ECONOMIC COMPUTATIONS  
 FLOWS IN CUBIC FEET PER SECOND (CUBIC METERS PER SECOND)  
 AREA IN SQUARE MILES (SQUARE KILOMETERS)

RATIOS APPLIED TO FLOWS

OPERATION STATION AREA PLAN RATIO 1 RATIO 2  
 .50 1.00

HYDROGRAPH AT INFLOW 1.19 1 3731. 7463.  
 . . . . . ( 3.00) ( 105.66) 211.32

ROUTED TO DAM 1.19 1 1133. 2696.  
 . . . . . ( 3.00) ( 32.00) 76.34

PLAN 1 . . . . . INITIAL VALUE SPILLWAY CREST TOP OF DAM  
 . . . . . 1145.00 1145.00 1160.00  
 ELEVATION STORAGE 4751. 4751. 7457.  
 OUTFLOW 0. 0. 8143.

RATIO .50 1.00  
 BP . . . . . MAXIMUM DEPTH MAXIMUM STORAGE MAXIMUM OUTFLOW DURATION OVER TOP MAX OUTFLOW TIME OF FAILURE  
 PMF . . . . . W.S.ELEV OVER DAM AC-FT CFS HOURS HOURS HOURS  
 .50 1149.19 0.00 5427. 1133. 0.00 42.33 0.00  
 1.00 1152.21 0.00 5953. 2696. 0.00 41.83 0.00

Output Summary  
 Various PMF Events  
 New Viburnum Dam  
 MO 31231  
 B9

11 NEW VERNUM DAM, MO. 31231, IRON COUNTY, MISSOURI.  
12 WOODWARD-CLYDE CONSULTANTS, HOUSTON JOB 006224.  
13 PROBABILISTIC FLOOD - 100 YEAR.

Input Data  
1% Probability Event  
New Viburnum Dam  
MO 31231  
B10

[illegible]

21	3A 172.	207.	244.	284.	1090.	1100.	1110.	1120.	1130.	1140.
22	3E 1050.	1060.	1070.	1080.						
23	3E 1150.	1160.	1170.	1180.						
24	3E 1145.									
25	3D 1160.	2.9	1.5							
26	3L 0.	457.	900.							
27	3V 1100.	1100.1	1170.							
28	K 1.99									

Input Data  
 1% Probability Event  
 New Viburnum Dam  
 MOL 31231  
 B11

... TIME 13.20.30.  
... DATE 01.07.05.

~~JOB SPECIFICATION~~

## SUB-AREA RUNOFF COMPUTATION

MAIN STA. 10-LESTERVILLE, PREQ= 1.0, INTERVAL=10.0 MIN., DURATION=48 HRS.

ISTAO	ICOMP	IECON	ITAPE	JPLY	JPPT	INAME	ISTAGE	TAUTO
0	0	0	0	0	0	1	0	0

## HYDROGRAPH DATA

TW00C	TUNG	PARGN	JMNP	TRSDA	TRSPC	RATIO	ISMOV	ISAME	LOCAT
.....	2	41.1	0.00	1.14	1.00	0.000	0	0	0

~~PRECIP-DATA~~

[illegible]

Output Summary  
1% Probability Event  
New Viburnum Dam  
MO 31231  
B12

[illegible]

LEADPT	STKR	DLTKR	RTIOL	ERATN	STKRS	RTIOK	STRTL	CNSTL	ALSMX	RTIMP
0.00	0.00	0.00	0.00	0.00	0.00	1.00	1.00	77.00	0.00	20.00

CURVE NO = -77.00 WEYNESS = -1.00 EFFECT CN = 77.00

YC= 0.90 LAC= .66

## STRTO# -2.00 QRCN# -.05 RTOR= 5.00

[illegible]

NO.0A	HR. MM	PERIOD	RAIN	EXCS	LOSS	COMP. Q	NO.0A	HR. MM	PERIOD	RAIN	EXCS	LOSS	COMP. Q
0000	00	00	00	00	00	00	0000	00	00	00	00	00	00

[illegible]



Output Summary  
1% Probability Event  
New Viburnum Dam  
MO 31281  
B14

1.01	5.10	31	.01	.00	.01	9.	1.02	9.10	175	.01	.01	.01	.01	34.
1.01	5.20	32	.01	.00	.01	9.	1.02	9.20	176	.01	.01	.01	.01	35.
1.01	5.30	33	.01	.00	.01	9.	1.02	9.30	177	.01	.01	.01	.01	36.
1.01	5.40	34	.01	.00	.01	9.	1.02	9.40	178	.01	.01	.01	.01	37.
1.01	5.50	35	.01	.00	.01	9.	1.02	9.50	179	.01	.01	.01	.01	38.
1.01	6.00	36	.01	.00	.01	9.	1.02	6.00	180	.01	.01	.01	.01	39.
1.01	6.10	37	.01	.00	.01	9.	1.02	6.10	181	.03	.02	.02	.01	40.
1.01	6.20	38	.01	.00	.01	9.	1.02	6.20	182	.03	.02	.02	.01	41.
1.01	6.30	39	.01	.00	.01	9.	1.02	6.30	183	.03	.02	.02	.01	42.
1.01	6.40	40	.01	.00	.01	9.	1.02	6.40	184	.03	.02	.02	.01	43.
1.01	6.50	41	.01	.00	.01	9.	1.02	6.50	185	.03	.02	.02	.01	44.
1.01	7.00	42	.01	.00	.01	9.	1.02	7.00	186	.03	.02	.02	.01	45.
1.01	7.10	43	.01	.00	.01	9.	1.02	7.10	187	.03	.02	.02	.01	46.
1.01	7.20	44	.01	.00	.01	9.	1.02	7.20	188	.03	.02	.02	.01	47.
1.01	7.30	45	.01	.00	.01	9.	1.02	7.30	189	.03	.02	.02	.01	48.
1.01	7.40	46	.01	.00	.01	9.	1.02	7.40	190	.03	.02	.02	.01	49.
1.01	7.50	47	.01	.00	.01	9.	1.02	7.50	191	.03	.02	.02	.01	50.
1.01	8.00	48	.01	.00	.01	9.	1.02	8.00	192	.03	.02	.02	.01	51.
1.01	8.10	49	.01	.00	.01	9.	1.02	8.10	193	.03	.02	.02	.01	52.
1.01	8.20	50	.01	.00	.01	9.	1.02	8.20	194	.03	.02	.02	.01	53.
1.01	8.30	51	.01	.00	.01	9.	1.02	8.30	195	.03	.02	.02	.01	54.
1.01	8.40	52	.01	.00	.01	9.	1.02	8.40	196	.03	.02	.02	.01	55.
1.01	8.50	53	.01	.00	.01	9.	1.02	8.50	197	.03	.02	.02	.01	56.
1.01	9.00	54	.01	.00	.01	9.	1.02	9.00	198	.03	.02	.02	.01	57.
1.01	9.10	55	.01	.00	.01	9.	1.02	9.10	199	.03	.02	.02	.01	58.
1.01	9.20	56	.01	.00	.01	9.	1.02	9.20	200	.03	.02	.02	.01	59.
1.01	9.30	57	.01	.00	.01	9.	1.02	9.30	201	.03	.02	.02	.01	60.
1.01	9.40	58	.01	.00	.01	9.	1.02	9.40	202	.03	.02	.02	.01	61.
1.01	9.50	59	.01	.00	.01	9.	1.02	9.50	203	.03	.02	.02	.01	62.
1.01	10.00	60	.01	.00	.01	9.	1.02	10.00	204	.03	.02	.02	.01	63.
1.01	10.10	61	.01	.00	.01	9.	1.02	10.10	205	.03	.02	.02	.01	64.
1.01	10.20	62	.01	.00	.01	9.	1.02	10.20	206	.03	.02	.02	.01	65.
1.01	10.30	63	.01	.00	.01	9.	1.02	10.30	207	.03	.02	.02	.01	66.
1.01	10.40	64	.01	.00	.01	9.	1.02	10.40	208	.03	.02	.02	.01	67.
1.01	10.50	65	.01	.00	.01	10.	1.02	10.50	209	.03	.02	.02	.01	68.
1.01	11.00	66	.01	.00	.01	10.	1.02	11.00	210	.03	.02	.02	.01	69.
1.01	11.10	67	.01	.00	.01	10.	1.02	11.10	211	.03	.02	.02	.01	70.
1.01	11.20	68	.01	.00	.01	10.	1.02	11.20	212	.03	.02	.02	.01	71.
1.01	11.30	69	.01	.00	.01	10.	1.02	11.30	213	.03	.02	.02	.01	72.
1.01	11.40	70	.01	.00	.01	11.	1.02	11.40	214	.03	.02	.02	.01	73.
1.01	11.50	71	.01	.00	.01	11.	1.02	11.50	215	.03	.02	.02	.01	74.
1.01	12.00	72	.01	.00	.01	11.	1.02	12.00	216	.03	.02	.02	.01	75.
1.01	12.10	73	.01	.00	.01	11.	1.02	12.10	217	.05	.04	.04	.01	76.
1.01	12.20	74	.01	.00	.01	11.	1.02	12.20	218	.05	.04	.04	.01	77.
1.01	12.30	75	.01	.00	.01	12.	1.02	12.30	219	.05	.04	.04	.01	78.
1.01	12.40	76	.01	.00	.01	12.	1.02	12.40	220	.05	.04	.04	.01	79.
1.01	12.50	77	.01	.00	.01	12.	1.02	12.50	221	.05	.04	.04	.01	80.
1.01	13.00	78	.01	.00	.01	12.	1.02	13.00	222	.05	.04	.04	.01	81.
1.01	13.10	79	.01	.00	.01	13.	1.02	13.10	223	.05	.04	.04	.01	82.
1.01	13.20	80	.01	.00	.01	13.	1.02	13.20	224	.05	.04	.04	.01	83.
1.01	13.30	81	.01	.00	.01	13.	1.02	13.30	225	.05	.04	.04	.01	84.
1.01	13.40	82	.01	.00	.01	13.	1.02	13.40	226	.07	.04	.04	.01	85.
1.01	13.50	83	.01	.00	.01	13.	1.02	13.50	227	.07	.04	.04	.01	86.
1.01	14.00	84	.01	.00	.01	14.	1.02	14.00	228	.07	.04	.04	.01	87.
1.01	14.10	85	.01	.00	.01	14.	1.02	14.10	229	.12	.09	.09	.02	88.
1.01	14.20	86	.01	.00	.01	14.	1.02	14.20	230	.12	.10	.10	.02	89.
1.01	14.30	87	.01	.00	.01	14.	1.02	14.30	231	.12	.10	.10	.02	90.
1.01	14.40	88	.01	.00	.01	14.	1.02	14.40	232	.29	.23	.23	.04	91.
1.01	14.50	89	.01	.00	.01	15.	1.02	14.50	233	.28	.24	.24	.04	92.
1.01	15.00	90	.01	.00	.01	15.	1.02	15.00	234	.65	.56	.56	.09	93.

1	15.10	.01	.00	.01	.02	15.10	233	1.22	.04	1215
2	15.20	.01	.00	.01	.02	15.20	236	.53	.49	1215
3	15.30	.01	.00	.01	.02	15.30	237	.28	.26	1215
4	15.40	.01	.00	.01	.02	15.40	238	.12	.11	2014
5	15.50	.01	.00	.01	.02	15.50	239	.12	.11	2014
6	16.00	.01	.00	.01	.02	16.00	240	.12	.11	1821
7	16.10	.01	.00	.01	.02	16.10	241	.07	.06	1215
8	16.20	.01	.00	.01	.02	16.20	242	.07	.06	1215
9	16.30	.01	.00	.01	.02	16.30	243	.07	.06	985
10	16.40	.01	.00	.01	.02	16.40	244	.09	.09	772
11	16.50	.01	.00	.01	.02	16.50	245	.05	.05	625
12	17.00	.01	.00	.01	.02	17.00	246	.05	.05	512
13	17.10	.01	.00	.01	.02	17.10	247	.05	.05	425
14	17.20	.01	.00	.01	.02	17.20	248	.05	.05	364
15	17.30	.01	.00	.01	.02	17.30	249	.05	.05	319
16	17.40	.01	.00	.01	.02	17.40	250	.09	.09	277
17	17.50	.01	.00	.01	.02	17.50	251	.05	.05	266
18	18.00	.01	.00	.01	.02	18.00	252	.05	.05	251
19	18.10	.01	.00	.01	.02	18.10	253	.01	.01	237
20	18.20	.01	.00	.01	.02	18.20	254	.01	.01	219
21	18.30	.01	.00	.01	.02	18.30	255	.01	.01	193
22	18.40	.01	.00	.01	.02	18.40	256	.01	.01	173
23	18.50	.01	.00	.01	.02	18.50	257	.01	.01	154
24	19.00	.01	.00	.01	.02	19.00	258	.01	.01	132
25	19.10	.01	.00	.01	.02	19.10	259	.01	.01	125
26	19.20	.01	.00	.01	.02	19.20	260	.01	.01	125
27	19.30	.01	.00	.01	.02	19.30	261	.01	.01	125
28	19.40	.01	.00	.01	.02	19.40	262	.01	.01	125
29	19.50	.01	.00	.01	.02	19.50	263	.01	.01	125
30	20.00	.01	.00	.01	.02	20.00	264	.01	.01	125
31	20.10	.01	.00	.01	.02	20.10	265	.01	.01	125
32	20.20	.01	.00	.01	.02	20.20	266	.01	.01	125
33	20.30	.01	.00	.01	.02	20.30	267	.01	.01	125
34	20.40	.01	.00	.01	.02	20.40	268	.01	.01	125
35	20.50	.01	.00	.01	.02	20.50	269	.01	.01	125
36	21.00	.01	.00	.01	.02	21.00	270	.01	.01	125
37	21.10	.01	.00	.01	.02	21.10	271	.01	.01	125
38	21.20	.01	.00	.01	.02	21.20	272	.01	.01	125
39	21.30	.01	.00	.01	.02	21.30	273	.01	.01	125
40	21.40	.01	.00	.01	.02	21.40	274	.01	.01	125
41	21.50	.01	.00	.01	.02	21.50	275	.01	.01	125
42	22.00	.01	.00	.01	.02	22.00	276	.01	.01	125
43	22.10	.01	.00	.01	.02	22.10	277	.01	.01	125
44	22.20	.01	.00	.01	.02	22.20	278	.01	.01	125
45	22.30	.01	.00	.01	.02	22.30	279	.01	.01	125
46	22.40	.01	.00	.01	.02	22.40	280	.01	.01	125
47	22.50	.01	.00	.01	.02	22.50	281	.01	.01	125
48	23.00	.01	.00	.01	.02	23.00	282	.01	.01	125
49	23.10	.01	.00	.01	.02	23.10	283	.01	.01	125
50	23.20	.01	.00	.01	.02	23.20	284	.01	.01	125
51	23.30	.01	.00	.01	.02	23.30	285	.01	.01	125
52	23.40	.01	.00	.01	.02	23.40	286	.01	.01	125
53	23.50	.01	.00	.01	.02	23.50	287	.01	.01	125
54	0.00	.01	.00	.01	1.03	0.00	288	.01	.01	125

Output Summary  
1% Probability Event  
New Viburnum Dam  
MO 31231  
B15

SUM 8.88 6.65 2.23 30315  
1 226.11 169.11 57.11 858.431

PEAK 2065. CFS 6-HOUR 594. 24-HOUR 197. 72-HOUR 105. TOTAL VOLUME 30295.

RUNOFF SUMMARY, AVERAGE FLOW IN CUBIC FEET PER SECOND (CUBIC METERS PER SECOND)  
AREA IN SQUARE MILES (SQUARE KILOMETERS)

HYDROGRAPH AT INFLOW		PEAK	6-HOUR	24-HOUR	72-HOUR	AREA
		2085.	599.	197.	105.	1.19
		59.0511	16.9611	9.5811	2.9811	3.081
ROUTED TO		DAM	305.	273.	104.	54.
			0.6411	7.7211	2.9311	1.5211
						1.19
						3.081

PLAN 1 .....	INITIAL VALUE	SPILLWAY CHEST	TOP OF DAM
	1145.00	1145.00	1160.00
	4751.	4751.	7457.
	0.	0.	9143.

RATIO OF PMF		MAXIMUM DEPTH OVER DAM	MAXIMUM STORAGE AC-FT	MAXIMUM OUTFLOW CFS	DURATION OVER TOP HOURS	TIME OF MAX OUTFLOW HOURS	TIME OF FAILURE HOURS
1.00	1100.82	0.00	9036.	305.	0.00	41.50	0.00

Output Summary  
1% Probability Event  
New Vifburnum Dam  
MO 31231  
B16

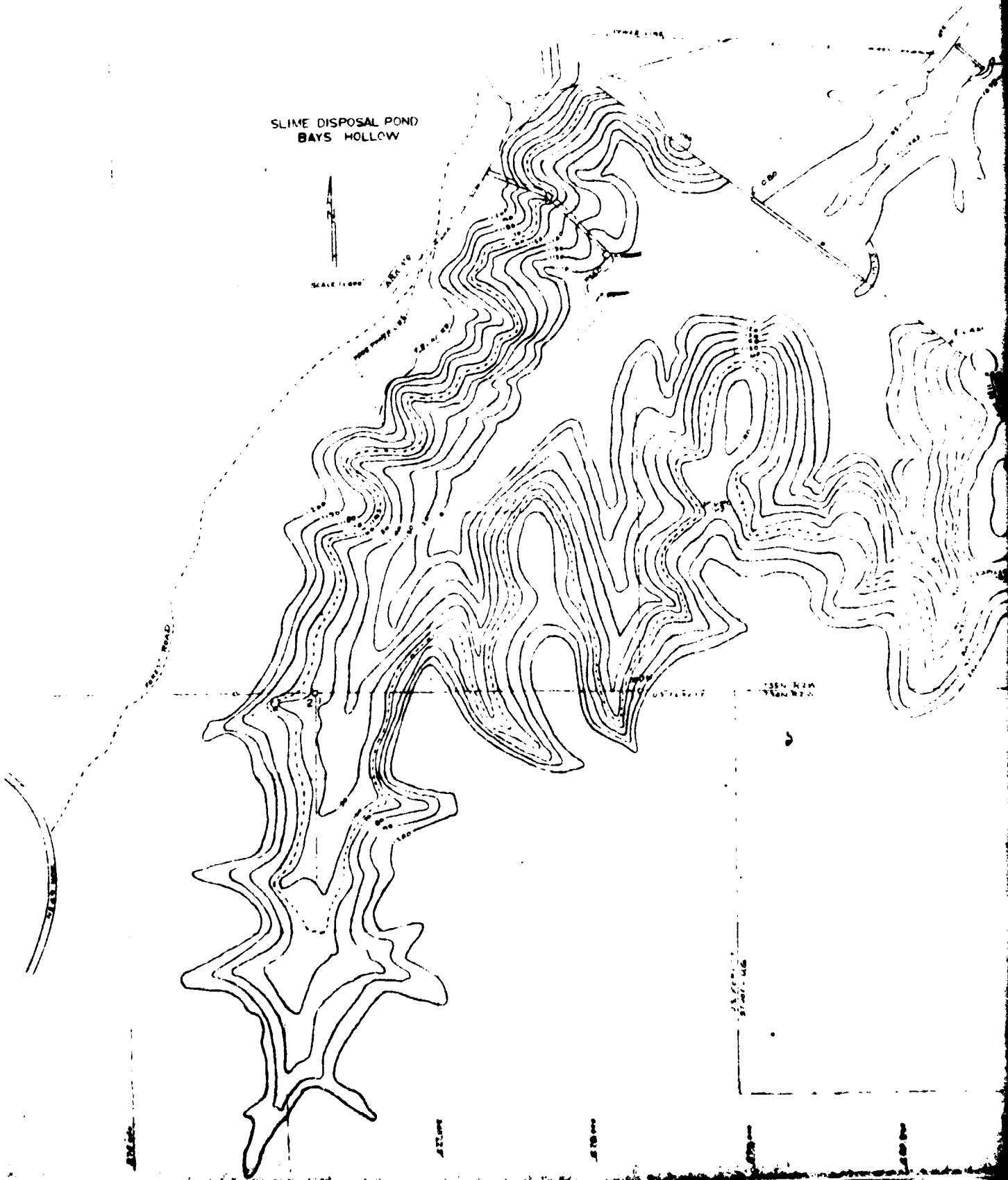
**APPENDIX C**

Design Drawings by St Joe Lead Co

SLIME DISPOSAL POND  
BAYS HOLLOW



SCALE 1:1000



600

57750

59000

59

NAME OF AREA  
10000  
10000  
10000

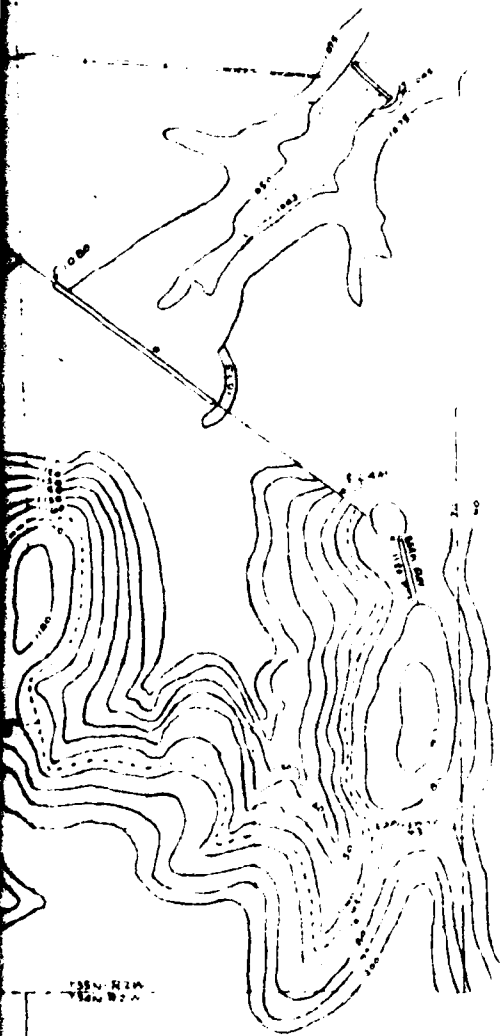
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NAME OF AREA  
10000  
10000  
10000

US 11187

59

57750



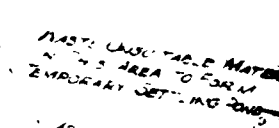
10000  
10000

5

10000  
10000

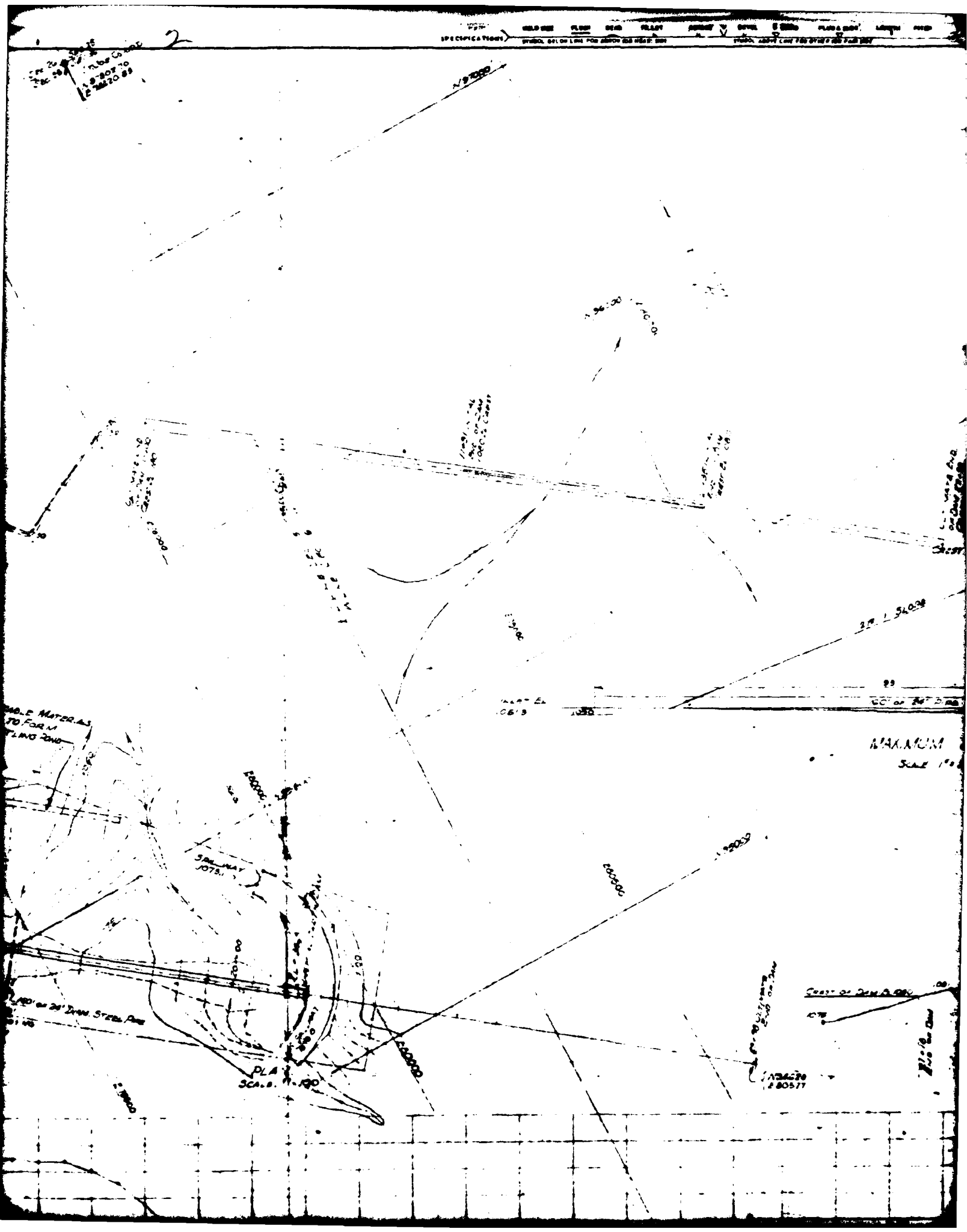
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SEP 26 1964



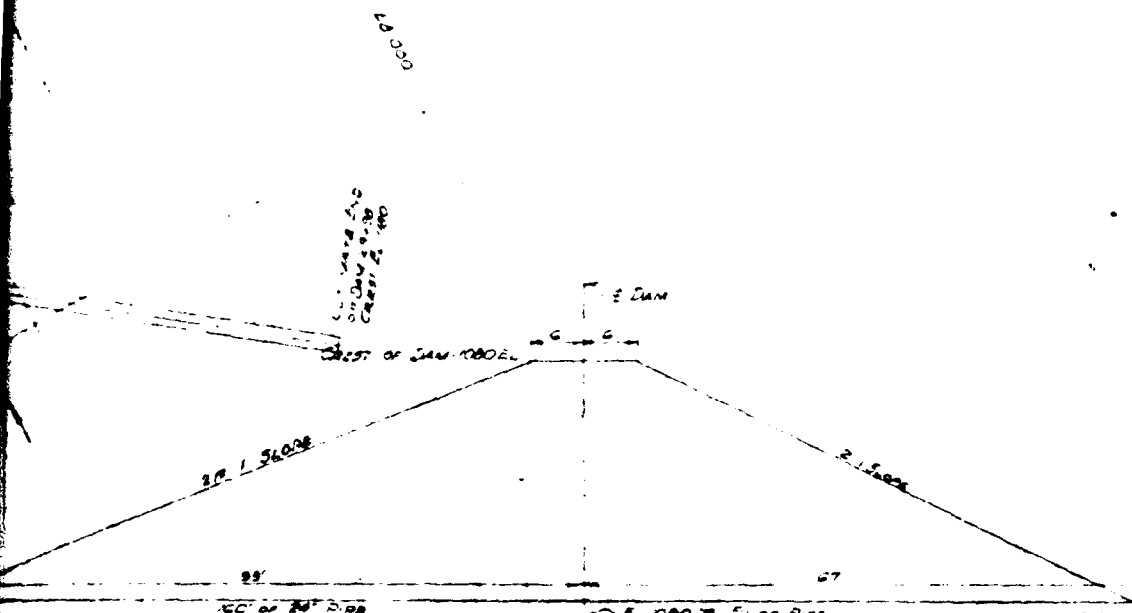
2

100-100-100  
 100-100-100  
 100-100-100



MAXIMUM  
 SCALE 1" = 10'



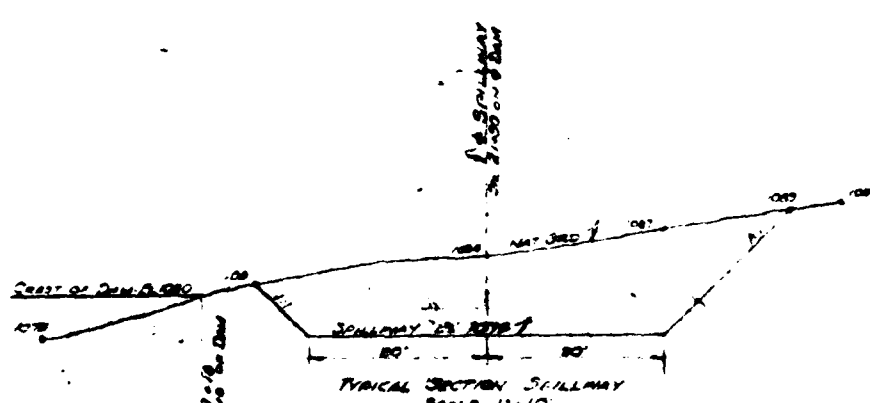


MAXIMUM SECTION

SCALE 1"=10'

8" 24" PIPE - EXCAVATE TO IMPERVIOUS WATER AL.

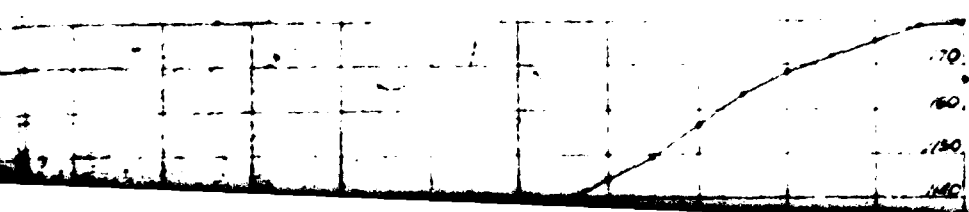
OUTSIDE OF 24" PIPE - EL. 99.027

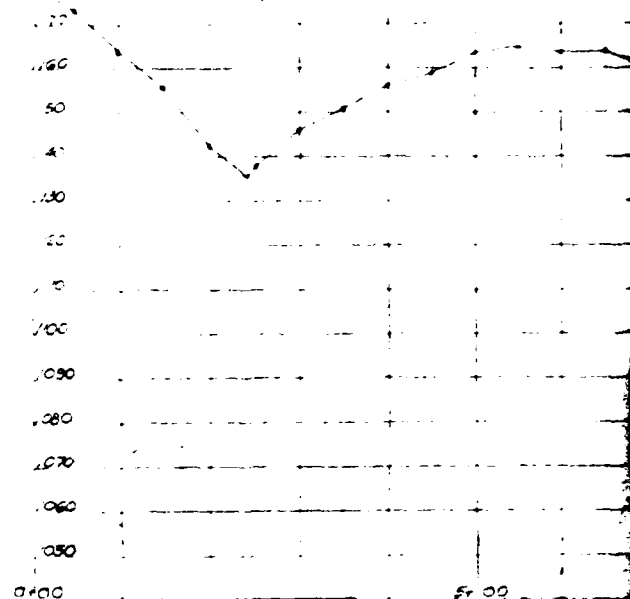
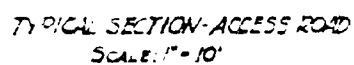


TYPICAL SECTION SPILLWAY

SCALE 1"=10'

POINT	ST. 0.00
1.00	
2.00	
3.00	
4.00	
5.00	
6.00	
7.00	
8.00	
9.00	
10.00	
11.00	
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42.00	
43.00	
44.00	
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46.00	
47.00	
48.00	
49.00	
50.00	





TOLERANCE		V-FORMALY PUNCH		V-FOR PUNCH		V-HARD BARS		V-ORDINARY MACHINE BARS		V-FINE MACHINE BARS		V-POLISH		V-ROLL FORM		V-LAP		V-AS MANUFACTURED		V-TRUSS CUT		V-FRAME		FRACTURE		BOLTING LENGTH		TOLERANCE	
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30



# MAXIMUM SECTION

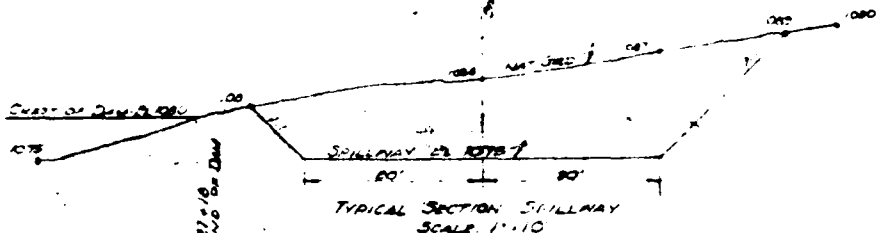
SCALE 1"=10'

1219 8.1

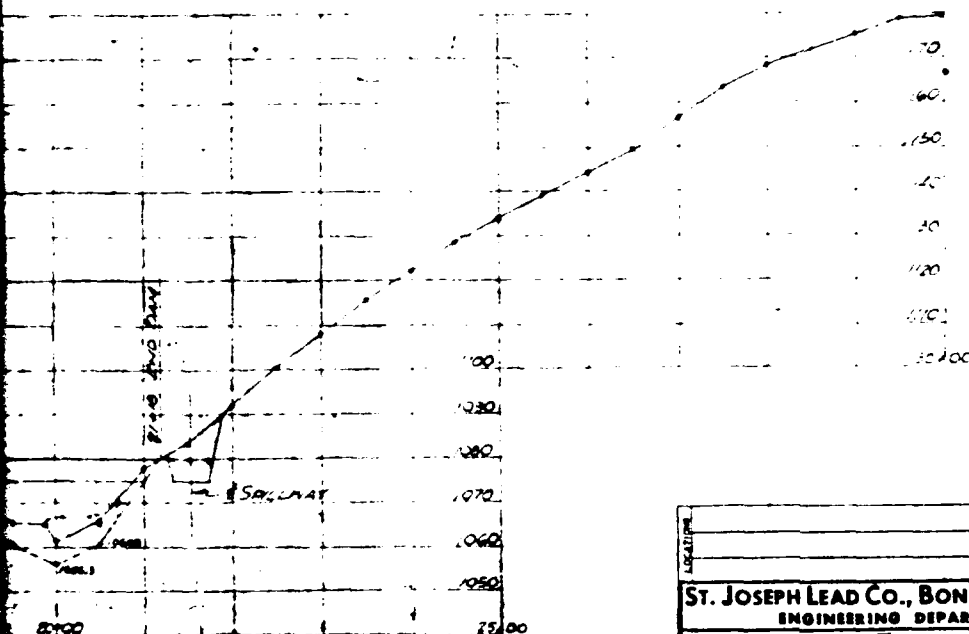
8' x 30' KENWAY - EXCAVATE TO IMPERVIOUS MATERIAL

OUTLET OF 24" PIPE - E. 06027

8' x 30' KENWAY - EXCAVATE TO IMPERVIOUS MATERIAL



106428  
200577



ST. JOSEPH LEAD CO., BONNE TERRE, MO.			
ENGINEERING DEPARTMENT			
BURNUM TAILINGS DISPOSAL			
PROPOSED DAM			
PLAN, PROFILE & SECTIONS			
SCALE AS SHOWN	DESIGNED BY C. D. JOY	CHECKED BY	DATE
NO. 117	STATIONED C. D. JOY	DATE	NO. 117
DWG. NO. 70X167-4			

## **APPENDIX D**

Corps of Engineers Notification of Sinkholes

11 East Adams Street  
Suite 1500  
Chicago, Illinois 60603  
312-939-1000  
Telex 253875 (WOODWARD CGO)

## Woodward-Clyde Consultants

6 March 1981  
Y9C00138-2

Department of the Army  
St Louis District, Corps of Engineers  
210 Tucker Boulevard, North  
St Louis, Missouri 63101

Attention: Mr Jerry Phelan

Re: Contract DACW 43-80-C-0066  
Safety Inspection of Non-Federal Dams

Gentlemen:

This letter is in response to our telephone call to you 6 March 1981. The call was regarding our inspection of New Viburnum Tailings Dam, MO 31231. As we reported in our phone call, our field inspection of the dam on 24 February 1981 revealed no structural instability of the embankment. A pipe was noted at the toe of the dam, flowing an estimated 100 to 150 gal/min. Following the inspection, we inquired as to the function of the pipe and it was described to us as a drain for a spring at the right abutment.

During the preparation of our draft report, we located photos taken of the dam during a November 1980 flight over the area. On these photos, a feature was noted that appears to be a sinkhole, estimated to be 20 to 30 ft in diameter. Since the time of the aerial photos, tailings have been deposited over this feature and no evidence of it was noted in the recent visual inspection.

In as much as sinkhole development on this type of dam is cause for concern, we believe we had to inform you of our findings as soon as possible rather than wait for the submittal of the draft or final inspection report.

I have included the photos taken during the November 1980 flight for your use. Additional prints can be made if you so request.

We understand that we are to continue to prepare our draft report for your review. We also understand that SLD will inform the Missouri Dam Safety Office and the owner of the dam, St Joe Lead Co, of this evidence of sinkhole.

Consulting Engineers, Geologists  
and Environmental Scientists

Offices in Other Principal Cities



Page 2

Our contacts with St Loe Lead Co. have been through Mr John Kennedy, Mr John Carter, who accompanied us on the inspection of this dam, and Mr Jack Krokroskia, Operations Manager. The phone number for St Joe Lead Co. is (314)244-5261. The address we have been given for our reports is St Joe Lead Co., P.O. Box 500, Viburnum, Missouri 65566, Attention: Mr Jack Krokroskia.

Very truly yours,



Richard G. Berggreen

RGB/cf



Photographs included in letter to SLD 6 March 1981  
(Photos taken in November 1980)



**DATE**  
**ILME**